TRANSIT SYSTEMS IN THE US AND GERMANY -

A COMPARISON

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TRANSIT SYSTEMS IN THE US AND GERMANY - A COMPARISON

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	Alternating Current
AEG	Allgemeine Electricitäts-Gesellschaft
AG	Aktiengesellschaft (transl.: public company)
AKN	Eisenbahn Altona-Kaltenkirchen-Neumünster
AVG	Albtal Verkehrsgesellschaft
BOStrab	Straßenbahn Bau- und Betriebsordung
BRT	Bus Rapid Transit
BVG	Berliner Verkehrsgesellschaft
CCT	Cobb Community Transit
CTRAN	Clayton County Transit
DB	Deutsche Bahn
DC	Direct Current
EBO	Eisenbahn Bau- und Betriebsordnung
FTA	Federal Transit Administration
GCT	Gwinnett County Transit
GmbH	Gesellschaft mit beschränkter Haftung (transl.: Limited)
GRTA	Georgia Regional Transportation Authority
GVFG	Gemeindeverkehrsfinanzierungsgesetz
HADAG	Hafendampfschiffahrts-Actien-Gesellschaft
HHA	Hamburger Hochbahn AG
HVV	Hamburger Verkehrsverbund
Hz	Hertz
ICE	Intercity-Express

kV	Kilovolt
KVV	Karlsruher Verkehrsverbund
LRT	Light-Rail Transit
MARTA	Metropolitan Atlanta Rapid Transit Authority
MVG	Münchner Verkehrsgesellschaft
MVV	Müncher Verkehrs- und Tarifverbund
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
US	United States
VBB	Verkehrsverbund Berlin-Brandenburg

SUMMARY

This thesis compares different public urban transit systems in the Federal Republic of Germany to the public urban transit system in the Atlanta, Georgia region in the United States. Regions and cities in Germany with comparable population size and density to the Atlanta region and the city of Atlanta were selected to assess differences in the transit systems regarding network layout and operational and financial characteristics. Performance measures such as ridership, headways and number of lines and stations were used to compare the systems and their service quality. The results suggest that the Atlanta region faces strong comparative challenges such as low population density and sprawl development, thus resulting in lower quality services and worse performance than its German counterparts. German cities rely much more on rail systems than Atlanta, where bus service provides the most geographic coverage.

CHAPTER 1

INTRODUCTION AND METHODOLOGY

1.1 Introduction

Having both lived and studied transportation in the United States and the Federal Republic of Germany, the author has had many encounters with prejudices and half-truths about the other country's public transit systems. "Germans have good transit systems that would never work here" and "You will need a car when you move to the US - they don't have transit over there" are just some of the opinions one hears when talking about transit in the respective countries. But how do the transit systems really compare? Has anyone ever really tried to compare transit systems in both countries? How is it possible to know if a transit system is "better" or "worse" than another and how would this be measured? These questions and many others have motivated this research, which compares Atlanta's transit system with selected systems in German cities to find out how different they really are.

The objective of this research is to compare the urban public transit system in the Atlanta, Georgia region of the United States with the transit systems in comparable regions in the Federal Republic of Germany. Data was collected from the respective transit agencies and other sources concerning network characteristics, operational performance and financial effectiveness of the selected transit systems. The data was then used to compare and interpret the differences among the various transit systems to be able to understand how effectiveness and success differ in each city.

It is the belief of the author that comparisons among transit systems such as the one conducted in this study can help to identify shortcomings and possible improvements in the respective transit systems to attract more riders and to be more economically efficient.

1.2 Methodology

1.2.1 Choice of Cities

Five German cities were picked in this research to compare to the Atlanta region. The cities chosen were, in order of population size:

- Berlin
- Hamburg
- Munich
- Hanover
- Karlsruhe

Berlin, Hamburg and Munich were chosen because they are the three most populous cities in Germany and their population is closest to the population of the Atlanta region. In fact, the population of Berlin is almost identical to the population of the central five-county Atlanta region. Hanover and Karlsruhe, on the other hand, were chosen because they have a similar population to the city of Atlanta itself (Hanover has slightly more, Karlsruhe slightly less). Facing the challenge of being medium-sized cities not suitable for subway operation, Hanover and Karlsruhe have both built transit systems that might prove of interest for the Atlanta region.

1.2.2 Choice of Transit Systems

This research included only fixed route transit systems that offer continuous service at least during the entire day time (6am-8pm). Transit systems that are not considered to be “urban” by the author were not included in this research. This included systems that have most of their stations outside of the city boundaries and/or only have a very limited number of stops inside the city (e.g., the regional trains in Germany usually only stop at one or two rail stations in each city). Because of the special spatial layout of the city and region of Atlanta with high sprawl and hardly delimitable urban areas, all major transit services in the five county central Metropolitan Atlanta area that meet the continuous operation criterion have been included in this research even if they do not mainly operate in the city itself.

In order to gain a deeper insight into the different characteristics of the chosen transit systems, the first part of this research collected information about the different transit services offered in each city and region and determined which agency or public body runs each system and how the transit “landscape” is organized in general. The chosen transit systems for this research are:

Berlin:

- S-Bahn Berlin
- U-Bahn Berlin
- Berlin Streetcar
- Berlin Bus

Hamburg:

- S-Bahn Hamburg
- U-Bahn Hamburg
- Hamburg Bus

Munich:

- S-Bahn Munich
- U-Bahn Munich
- Munich Streetcar
- Munich Bus

Hanover:

- S-Bahn Hanover
- Stadtbahn Hanover (LRT)
- Hanover Bus

Karlsruhe:

- Regio-Stadtbahn Karlsruhe
- Karlsruhe Streetcar
- Karlsruhe Bus

Atlanta:

- MARTA Rail
- MARTA Bus
- CCT Bus
- GCT Bus

1.2.3 Collected Data

To provide a comprehensive overview of system characteristics and to familiarize the reader with the German systems, a detailed description of each of the systems was developed. This overview includes a brief description of the system's history and the network characteristics that might explain possible differences in the systems. The data for this overview was mainly obtained from the respective transit agencies via e-mail communications.

Data about certain system characteristics was collected in order to compare the systems based on performance measures and service data. Data was collected in three different performance areas and included the following information:

- Network characteristics
    - number of transit lines
    - total track length (only for rail systems)
    - total transit line length (sum of all lines)
    - average line length (depending on data availability average line length and total line length have been calculated using the available value and the number of lines)
    - number of stations (if stations for both directions of a line exist at the same location this only counts as one station)
    - average station spacing (depending on data availability the average station spacing has been calculated using total transit line length and number of stations)

    - for the bus systems two additional parameters were included to better compare the networks based on the different population structure in Germany and the US:
        - number of bus lines per one million inhabitants
        - total line length per one million inhabitants
- Operational characteristics
    - total annual ridership (total unlinked trips)
    - total annual passenger miles
    - total annual train/bus miles
    - usual headways (most common headways during the given period of time for the lines of the respective system)
        - during rush hour/peak period times (usually at least 6am-9am and 4pm-6pm)
        - during non peak times (usually after 8pm)
    - weekday hours of operation (time between start of earliest and end of last service on a typical weekday)
- Financial characteristics
    - total operating cost (no “clean” demarcation possible since some transit agencies include depreciation and part of their capital cost in the operating cost while others don’t; it was attempted to only include typical operating costs such as labor, benefits, maintenance and energy)
    - ticket revenue (all revenue from tickets and passes)
    - fare structure (whether flat, zone-based or distance-based fares)

- ticket prices (price range for a single trip ticket without further discounts)

The data collection for this part of the research was done on a transit mode system basis (subway, streetcar, bus separately) except for the information about fare revenue and operating costs, which was collected on an agency basis. For interpretation, however, the data on the three Atlanta bus systems (MARTA, CCT, GCT) have been merged into one dataset to better compare the different cities.

Additional population and area data was collected for the six cities and their respective regions. For this research, the Atlanta region consisted of the five core counties: Fulton, DeKalb, Cobb, Gwinnett and Clayton. The region of each German city consisted of the service area of the respective transportation association that coordinates transit in and around each of the cities. For the case of Berlin the service area of the transportation association includes the whole state of Brandenburg. Because of this large service area and the fact that almost all investigated transit service is operated exclusively within the city of Berlin (except for a small number of S-Bahn stations) no region for Berlin was defined for this research.

The data for this research were collected almost exclusively from public agencies. The values have been taken either from reports, maps and fact sheets published by the respective agency (such as annual reports) or were obtained from the agencies directly by contacting them.

All distances have been converted into miles using the conversion factor of 1.60934 kilometer = 1 mile and all foreign currency has been converted to US dollars using an exchange rate of 1.40 US$ = 1.00 Euro which is an average rate of 2010/2011.

1.2.4 Definition of Rail System-Terms

German transit legislation distinguishes between “full” railroads and “other” rail-based urban transit systems regarding construction and operations. The construction and operation code for the “full” railroads is the “Eisenbahn-Bau- und Betriebsordnung” (EBO; trans.: Railroad Construction and Operations Code). It provides very clear guidelines and standards for parameters such as superelevation and curve radii, which all railroad companies in Germany must follow.[1] All S-Bahn systems in Germany (except for the Regio-Stadtbahn Karlsruhe) are operated entirely under the jurisdiction of this code and therefore are “full” railroads.

Standards for streetcar and subway operation, on the other hand, are organized in the “Straßenbahn-Bau- und Betriebsordnung” (BOStrab; trans.: Streetcar Construction and Operations Code). This code contains less strict and clear guidelines and parameters for streetcar and subway system design, allowing adjustment to constraints in dense urban areas (e.g. very small curve radii, sight distance without automated protection systems for streetcar operation, etc.).[2] All German streetcar and subway systems included in this research operate under the jurisdiction of the BOStrab.

A real hybrid system is the Regio-Stadtbahn Karlsruhe. It operates under the jurisdiction of both codes because it uses railroad tracks as well as streetcar tracks and therefore the rail cars have to meet both standards.

For this research the terms subway, metro and U-Bahn are used interchangeably. The German term U-Bahn stands either for “Unabhängige-Bahn” (trans.: Independent Rail) or “Untergrundbahn” (trans.: Underground Rail). The definition of a U-Bahn, subway or metro in this research is that it runs on entirely exclusive right of way with no level grade crossings to other traffic systems. This criterion is met by the MARTA rail system and the U-Bahns in Berlin, Hamburg and Munich. For this research, the MARTA rail system is included in the subway category because of its independent network although it is not officially called subway or metro by MARTA itself.

Because of their status as full railroad systems and their regional importance for commuters, the German S-Bahns are closer to what in America would probably be called "commuter rail." The German term S-Bahn usually stands for "Stadtschnellbahn" (trans.: Rapid-City-Rail) and because of their importance for intra-city transit (especially in Hamburg and Berlin) these systems should be placed somewhere between subways and commuter/regional rail. In this research these systems will be referred to as S-Bahn.

The definition of light-rail transit (frequently called "Stadtbahn" [trans.: City-Rail] in Germany) as it is used in this research includes all rail systems that still have level grade crossings with other traffic systems, but also run as a subway system on parts of their network. Given this definition the Stadtbahn system in Hanover is the only light-rail system included in this research.

As mentioned before the Regio-Stadtbahn Karlsruhe operates as a hybrid system on streetcar and railroad tracks with two-system rail cars under the jurisdiction of both EBO and BOStrab. In this research the term Regio-Stadtbahn is solely used for this kind of hybrid operation. For simplification purposes the Regio-Stadtbahn Karlsruhe will also be referred to as "S-Bahn Karlsruhe."

All other urban rail systems included in this research will be referred to as streetcars or the German equivalent term "Straßenbahn." The definition of a streetcar in this research includes that the lines frequently run in streets, in road lanes and/or on the shoulder or the median of roads.

1.2.5 Data Interpretation

The first part of the interpretation was to compare the cities among each other regarding total population, geographic area and population density since this is the basis on which the respective transit systems have been built. In addition to the population data, two normalized parameters have also been used for this comparison:

- the total ridership of all systems in each region divided by the population of the region and the city (ridership per capita)
- the total passenger miles of all systems in each region divided by the population of the region and the city (passenger miles per capita)

For the comparison and interpretation of the **network characteristics** the systems were divided into bus and rail systems. The data on the three Atlanta bus systems were aggregated as far as possible (except for the average station spacing) to form “one” Atlanta bus system. In each of the system groups (bus and rail) the systems were then compared with three different groups of parameters:

- line characteristics (total number of lines and average length)
- network size (total track [only rail] and total line length [for all])
- stations (number of stops and average spacing)

The systems were also divided into bus and rail systems for the comparison and interpretation of the **operational characteristics.** The following operations measures were chosen to compare the systems:

- ridership (total ridership and total ridership in relation to total line length (to see what the effect of offered service [line length] on the ridership is))
- transportation performance (total passenger miles divided by total ridership [to get a normalized expression for how long the average distances are that the riders ride on the system] and total passenger miles divided by total train/bus miles [to get a normalized expression for how many people are carried on each vehicle on average]
- offered service (typical headways and hours of operation)

In a last section, the systems were compared regarding their **financial characteristics** and performance. Because financial data was not available on a systems basis for all agencies, this comparison and interpretation was conducted on an agency basis, that is, financial and operational information for each agency were aggregated into one dataset. The categories and parameters for this part of the interpretation were:

- cost efficiency (total operating cost divided by both total passenger miles and total ridership)
- fare system (fare structure and ticket prices)
- cost recovery factor (total fare revenue divided by total operating costs)

1.3 Organization of the Thesis

The structure of this thesis follows the structure laid out in the methodology. The next section provides an overview on the literature published in this field of research and summarizes the most important findings. The data section presents the organizational and historical background of each city's transit system and provides an overview on the existing transit networks and a table showing all collected network, operations and financial measures. The following section interprets the collected data and the results are displayed. The last section provides a brief conclusion summarizing the main findings of this research and providing possible improvements and additions for future research.

CHAPTER 2

LITERATURE REVIEW AND LEGISLATIVE CONTEXT

This chapter summarizes relevant literature on transit system comparisons. Finding literature that compares transit systems in different countries was challenging. It was even difficult to find comparative literature about transit agencies inside the United States or inside any other country. The first section of this chapter describes key writings on transit system comparisons, while the second section presents the constitutional and legislative differences between Germany and the United States as they relate to transit service.

2.1 Literature on Transit System Comparisons

The most extensive review of transit systems internationally was conducted by Dr. Robert Cervero, a Professor of City and Regional Planning at the University of California, Berkeley. In his book, “The Transit Metropolis,”[3] Cervero provides a relatively broad overview and comparison of transit systems around the world. His objective is to show what in general makes a successful transit system and why transit in some places of the world is more successful than in others. Although he provides some comparative figures, he focuses his efforts more on policy and planning background and on the different “approaches” and boundary conditions in the cities.

Cervero defines four different types of transit metropolises, each having different ways of implementing effective and successful transit:

Type 1: "Adaptive Cities": He describes this type of city as "transit-oriented metropolises that have guided their urban growth" mostly along rail-served corridors or around rail nodes to establish transit-served communities around these rail lines.

The development in the "adaptive cities" occurs mostly around rail stations and consists of mixed land uses such as businesses and residential units to form small communities. The rail lines usually connect the outlying communities to the central business district as radial lines that cut through the greenbelts often formed or preserved between the outlying communities. Examples of this kind of city in Cervero's book are Stockholm (Sweden), Copenhagen (Denmark), Tokyo (Japan) and Singapore (Singapore).

Type 2: "Adaptive Transit": These cities have tried to adapt their transit systems to the challenges and difficulties that result from urban sprawl and the decline in population density in the urban environment. Instead of adapting and strongly regulating their land use and growth (as in Type 1 cities), these cities have allowed spread out development patterns and are therefore facing totally different problems.

For a transit system in this type of city to be successful it must compete with the automobile. Transit trips should provide door-to-door service, have very little waiting time, and most importantly, if possible, no transfers. Also a lot of trip origins and destinations in this type of city are not between distinct centers (such as residential centers in the suburbs and a central business district in the city center), but rather between different outlying sub-centers that have to be connected tangentially.

According to Cervero, there are three ways to adapt to this trip pattern:

1) Technology-based response, e.g., more flexible systems (Bus Rapid Transit, (Regio-)Stadtbahn)
2) Service reforms, e.g., schedule changes to minimize waiting and transfer time and transit centers where lines can connect in the suburbs
3) Flexibly routed paratransit, e.g., small shuttle buses or vans that operate door-to-door

These approaches could be summarized under the catchphrase "Don't create the city to serve transit, but create transit that serves the city."

Cervero's examples of cities for this type are Karlsruhe (Germany), Adelaide (Australia) and Mexico City (Mexico)

Type 3: "Hybrids" (adaptive transit and adaptive cities): These cities share the characteristics of both the adaptive cities and adaptive transit cities. They have allowed sprawl development, but at the same time have also concentrated development around rail lines. This type of city usually has secondary and tertiary activity and employment centers orbiting the central business district.

Type 4: "Strong Core Cities": As the name already states these cities have in common a strong core in their center. They use transit (usually light rail or streetcars/trams) to revitalize the built-up core of the city and to enrich the quality of urban living and establish transit-supportive built forms.

The examples in Cervero's book include Zürich (Switzerland) and Melbourne (Australia).

Cervero provides examples of cities for the four types and describes these cites in further detail. He provides a brief overview on the systems history, some operations parameters and focuses on special characteristics in the cities' planning efforts and policy approaches.

Cervero also analyzes two German cities, Munich and Karlsruhe, which because of their interesting characteristics and well known service quality are part of this study as well. Cervero's analysis of these cities suggests that both have very efficient transit systems.

Munich is regarded as a very efficient (high productivity based on employees and costs) system with very good service (high customer satisfaction, short headways, system is largely built out). He also states that Munich, despite facing some difficult trends (continuing sprawl, high automobile ownership), managed to establish one of the best transit systems in Europe even though construction and implementation of the major service providers in the city (the U-Bahn and S-Bahn) did not begin until shortly before the Olympic games in the city in the early 1970s.

Cervero also seems to be quite impressed by the transit system in the southwestern German city of Karlsruhe, which has established a so called Regio-

Stadtbahn (= regional-city-train as opposed to Straßenbahn = streetcar) whose lines reach far into the hinterland of the relatively small city.

He comes to the conclusion that especially in Germany it seems to be very important for both policy makers and the public to establish high quality rail transit service. The rail element seems to be particularly important when it comes to the mode choice decision of Germans and that busses alone will not be able to satisfy the public's transportation needs and wishes.

Michael Lewyn, who compared and reviewed the policies that led to different intensities of sprawl in Europe and the United States (and is thereby closely touching the topic of transportation and transit planning) comes to the conclusion that European cities usually have a significantly different shape and structure. This leads to more activities and higher density in the core of the city favoring the use of public transit. One of the causes of European cities having less sprawl than American cities seems to be different public policies.[4] A lot of European cities have very strict regulations regarding land development and permitted land usage and have significantly higher gasoline taxes discouraging the use of private automobiles.

It can also be assumed that strict regulation is not the only way to prevent sprawl since in some of Europe's most deregulated and liberal economies, like Switzerland and Ireland, sprawl appears even less than in strongly regulated countries like Germany and France. Transit use is even higher (e.g., in Switzerland the ratio of car trips to transit trips is about 2.3 while in the United States the same ratio is about 44.5 [4]).

Furthermore, the United States has a strict regulation of land development and some very strict zoning requirements often preventing the development of higher density city centers in suburban areas. If, for example, minimum parking availability and supply per apartment and business floor area regulations were deregulated, denser city centers could result helping also the development of transit systems. [4]

The strong influence of parking availability on urban development and thus on traveler behavior and the attractiveness of transit is also underlined by Hermann Knoflache, who says that parking "destroys all human scale structures and activities" and that "public transit under these circumstances [good and close parking availability throughout the city] has no chance anymore."[5] In his opinion, parking should be at least as far away from travel destinations as transit stations are and that parking costs should be on the same level as individual transit costs. Knoflacher also provides several case studies from different European cities that have successfully improved the state of non-motorized transport by implementing projects that encourage walking and transit use in the respective cities.

Breno Ramos Sampaio, who conducted an efficiency analysis of different transit systems by comparing European and Brazilian transit systems, finds that beside the necessity of reasonable land development and parking regulation policy there are several key elements that characterize good transit performance [6]:

- accessibility (good coverage of the area with stations)
- travel time
- trustworthiness (being on time)
- frequency
- capacity
- vehicle characteristics (age, conservation status, technology)

- adequate information and support facilities (covered stations, timetables etc.)

Another interesting transit system comparison has been conducted by Alla Reddy, who compared the subway system in New York with four Asian systems--Hong Kong, Singapore, Kuala Lumpur and Taipei. Besides the fact that the four Asian systems are much younger and therefore do not have to face the “state-of-good-repair” issues that the New York City subway has, at least since the 1970s, his main conclusions include that the Asian cities implement stronger transit-oriented development efforts and that transport system regulation in these cities is generally more comprehensive than in New York (and presumably in the US in general). The transit system in Singapore, for example, is owned by the same agency that also regulates traffic development, street construction and parking regulations. This enables Singapore’s transit agency to strive for a much more thorough approach in transportation planning and regulation in the city. Reddy also mentions that the transit-oriented development efforts in the Asian cities are much stronger than in New York City. [7]

Carlos Daganzo, who did an analysis of transit systems with respect to system design and operations, comes to the conclusion that transit systems should always be able to compete with traffic with regard to travel time and cost in order to be successful. Therefore, the transit system has to cover the region in both space and time. [8] In his analysis he stated that bus rapid transit systems (BRT) would always outperform metro systems and therefore should always be favored.

When comparing different transit systems, similar relationships among the variables often occur. Under the premise of cost efficiency, bus systems are almost always cheaper (in total and per passenger mile) than light rail systems or streetcars.

Metro systems, especially when large heavy trains are used, can be more efficient (in cost per passenger mile) while their overall costs (especially the initial capital costs) are of course much higher. [9] On the other hand, streetcars and light rail systems can increase the quality of public space by being visible on the surface and give the impression of a friendly and livable city. [5] These “soft factors” should always be considered in addition to economic performance measures.

In comparing European and Brazilian transit systems, Sampaio concludes that the main reasons for higher efficiency of some transit systems are that they:

1. “present a higher number of participants (in planning and administration), including central and local governments and associations representing communities” leading to “more equally distributed power.”
2. “offer a broad range of products, such as unitary and multiple trip tickets and cards for longer periods improving the quality of service.” Giving every potential customer the chance to get a ticket is perfectly suited for an individual situation so that nobody thinks he is disadvantaged. [6]

What seems to come across from all these references is that the efficiency and success of a transit system is based on a transparent planning structure with a broad range of participation throughout the community. A good transit system should also have a readily understood and diversified fare structure, good service and breadth of coverage in space and time in the service area. All attempts to provide a well-organized and well-administered transit system are of course undermined by “transit hostile” land development and zoning requirements, which show the importance of foresight and density-focused urban planning.

2.2 Public Transit Legislation in Germany and the US

Different constitutional traditions in Germany and the United States lead to distinctly different consideration of public transit in each country's respective legislation. This short overview is intended to provide basic knowledge on the different legislative foundations for urban public transit in both countries.

As it is stated in article 20, paragraph 1 of the German constitution:

"The Federal Republic of Germany is a democratic and social federal state." [11]

This sentence contains the basic foundation for the organization of public transit in Germany. As a federal state, Germany consists of sixteen different regional states similar to the states in the United States. Each of these states has its own parliament, executive government and system of courts. It is the responsibility of the state governments and parliaments to regulate areas such as education, the police and regional public transit. The democratic principle that is deeply rooted within the German constitution is the basis for the participation of the public in different stages of the planning process for infrastructure and public transit planning projects and for the fact that elected officials have the final say on plan adoption and implementation.

The fact that Germany is declared to be a social state by the constitution gives the state a certain responsibility to take care of its citizens. One of these responsibilities is the so called "Daseinsfürsorge" that literally means "provision of existence" and involves the right of every inhabitant to live a decent life by being able to reach the essential places for him/her to support their lives. This principle is set in the "Federal Spatial Planning Act," which states that one of the goals of spatial planning is to preserve the "Daseinsvorsorge" in the whole nation (article 2, paragraph 2, sub-paragraph 1). [12]

The Spatial Planning Act also determines that the states are to establish statewide and regional spatial plans that contain all areas for settlements and corridors for infrastructure (article 8).

The responsibility for the operation and construction of transit services that assures the implementation and perpetuation of these constitutional principles is divided into different parts. According to the constitution, the federal government and the legislature (in the following referred to as “the Federation”) have the sole responsibility for the lawmaking regarding the federal railroads (“Eisenbahnen des Bundes”) that are owned by the Federation (e.g. the “Deutsche Bahn” - German Rail) and for their administration and operation:

> *“The Federation shall have exclusive legislative power with respect to: (…) the operation of railways wholly or predominantly owned by the Federation (federal railways), the construction, maintenance and operation of railroad lines belonging to federal railways, and the levying of charges for the use of these lines;”* (article 73, paragraph 1) [11]

Regional rail transit on the other hand (no matter on whose tracks it is operated) lies within the responsibility of the states as it is determined in article 1 of the German “Regionalization Act” (“Regionalisierungs Gesetz”). [13] The states can delegate this responsibility to regional entities such as “transportation unions” between multiple counties and/or county-free cities. According to the “Regionalization Act” regional public transit (“Öffentlicher Personennahverkehr”) is transit in which the majority of the passengers have a mean trip length below 50 km (31 mi) or a mean travel time of less than one hour (article 2). This is to distinguish regional transit from long distance intercity transit that does not receive operational funding from the government. The "Regionalization Act" also states very clearly that the provision of a "sufficient" regional transit service for everyone is part of the "Daseinsfürsorge" making it an obligation for the states to provide it (article 1, paragraph 2).

To provide for regional public transit in all areas of its territory, the Federation in 2008 made a sum of 6.675 billion euros (about 9.345 billion dollars) available to the states for operation and implementation of public transit. [13] This sum is to increase by 1.5 percent every year and originates from the federal motor fuel tax ("Mineralölsteuer"). The money is distributed among the states according to fixed proportional factors and shall be used preferentially for the operation of regional rail transit. (article 6) [13]

In addition to these operations and capital funds for regional transit, the Federation also provides funding for the improvement of urban transportation infrastructure in the cities and communities, which is regulated in the "Community-Transit Financing Act" ("Gemeindeverkehrsfinanzierungsgesetz - GVFG"). [14] Under this law the cities and communities can get financial support of up to 75 percent of the cost for capital investments in urban transit or other projects (article 4, paragraph 1).

The operation of urban transit (streetcars, subways, light-rail and buses) is usually the responsibility of, and has to be funded by, the community on whose territory it is operated (e.g. a city or a county). In special cases different communities and cities have formed cooperative organizations in which they work together and join forces to operate and fund public transit (e.g. the "Region Hannover" mentioned later in this thesis).

There is no distinct right of citizens to have public transit in the laws of the United States. Public transit is not mentioned as one of the federal domains in the US

Constitution so that responsibility for its regulation and legislation falls to the states. [15] There is also no law in the US for preventing anyone from offering transit services (e.g. intercity coach operation) as long as they provide funding for it and meet motor vehicle safety standards.

If, on the other hand, a transit agency needs to get public funding (e.g., by implementing a regional sales tax) the state legislature has to pass a state law that enables the desired funding (so called enabling legislation). For example, to use the MARTA sales tax for transit purposes the Georgia General Assembly had to pass a law that enabled the voters in the respective areas to approve the taxation before the sales tax became reality. [16]

Although the Constitution does not provide a transit role for the federal government, the U.S. Congress created the Urban Mass Transit Administration in 1964 (now the Federal Transit Administration or FTA). The FTA provides federal capital funding for transit agencies in all states if they comply with certain standards set by the federal government. The grant recipients have to be public bodies in order to receive funding. The federal funds that are distributed by the FTA were most recently authorized in the "Safe, Accountable, Flexible, Efficient, Transportation Equity Act - A Legacy for Users" (SAFETEA-LU) passed by the US Congress in 2005. [17]

CHAPTER 3

CITY AND TRANSIT SYSTEM OVERVIEW

This chapter provides a brief overview of all transit systems included in this research. It is intended to provide basic information on transit system organization, history and network layout in each city. All data that has been collected and later interpreted in this research is presented in this chapter.

3.1 Berlin

The city of Berlin (which is congruent to the German state of Berlin) is Germany's capital and largest city by both area and population. With a total population of 3,442,675 people, it occupies an area of 892 km^2, roughly a quarter of the size of Rhode Island). [18] Berlin has a very large and extensive network of transit modes and services, including high-speed-rail connections to many other German (and European) cities such as the well known high-speed rail connection to Hamburg.

At the regional level and the surrounding state of Brandenburg, transit efforts are coordinated by the "Verkehrsverbund Berlin-Brandenburg" (VBB - transl.: Transportation Association Berlin-Brandenburg). Owned by the states of Berlin and Brandenburg and the counties and cities in the respective states, the VBB coordinates the transit services offered by 41 different transit agencies. Starting on April 1, 1999, the VBB offered a common fare structure for the entire service area, a structure consisting of a distance based/zonal fare system to facilitate access and use of the transit systems for the users. [19]

The major transit agencies in the city of Berlin are the Deutsche Bahn with its subsidiary DB Regio (offering regional trains and the commuter rail system called "S-Bahn") and the Berliner Verkehrsbetriebe (BVG - transl.: Transport Company of Berlin), which operates the subway (called "U-Bahn"), the streetcar network (in the following referred to as "Tram") and the local and express city buses. [20] The regional trains were not included in this analysis because they serve predominantly connections to other cities and not just into the suburbs of Berlin; they are not considered solely urban transit systems (although they are certainly used by some people for rides within the city).

3.1.1 S-Bahn Berlin

History

As with transit systems in many German cities the history of the S-Bahn Berlin began with the need for connecting emerging dead-end railroad stations of a growing city in the mid 1800s. The first rail traffic on the so called "Ringbahn" (trans.: circle-line) around what was then the city of Berlin was started in 1871 and the full ring of tracks around the city was completed in 1877. The Ringbahn connected several neighborhoods and railroad stations from which the Deutsche Reichsbahn (expl.: the national railroad of the German Empire) offered long-distance service to other cities of the Empire.

In 1882, the Stadtbahn (transl.: city-line), following an east-west alignment through the center of the city (and the Ringbahn), was opened. The Stadtbahn ran entirely on a viaduct to separate rail traffic from street and pedestrian traffic, and was the first railroad in Europe to be built in that style. Additional lines were added to connect the Ringbahn and the Stadtbahn with the suburbs and surrounding cities.

After experimenting with different electric power systems, the entire rail network was electrified beginning in 1928 through the addition of a “third” rail powered with 750 volt DC. Until the 1930s, the trains were officially operated under a new brand, “S-Bahn”, which stood for Stadt-Schnell-Bahn (trans.: fast city-train) and contrasted with the subway, which was called U-Bahn. The construction of a second connection through the city center, the Nord-Süd-S-Bahn (transl.: north-south-line), was finished in 1939 with most of the alignment in tunnels.

After World War II and the massive reconstruction efforts in the immediate post-war era, the S-Bahn experienced its most radical change with the construction of the Berlin Wall on August 13th 1961. The Wall cut across the Ringbahn, the Stadtbahn, the Nord-Süd-Bahn and some of the outgoing lines of the S-Bahn. Since it was no longer possible to travel freely between the western part of Berlin and the German Democratic Republic, many S-Bahn connections were discontinued. The system, however, was still operated by the national railroad company of the German Democratic Republic and thus was an easy target for boycott by the West Berlin population wanting to protest the division of the city. This accelerated the decay of the system even more. The S-Bahn, although steadily expanded in East-Berlin, was slowly dying in West Berlin with riders increasingly using the U-Bahn, which was owned by the City of (West)Berlin until 1983 when an agreement between the Senate of (West) Berlin and the national railroad of the GDR allowed West Berlin to take over the control and operation of the S-Bahn lines in West Berlin.

Following German Reunification in 1990 the S-Bahn operation was taken over by the West Berlin transit agency (BVG) and the unification contract between the two Germanies provided a plan to largely reconstruct the network and close all gaps that were created by the division. In 1994, the national railroads of East and West Germany were joined into what is known today as the Deutsche Bahn AG (trans.: German Rail) and the S-Bahn became a subsidiary of the newly formed corporation under which it is still operated today. [21]

Network

The S-Bahn Berlin network consists of three main lines (the circle line, the city-line [east-west] and the north-south-line) and several branches in the suburbs. The north-south line and the city-line meet at Friedrichstr. station in central Berlin. The transfer stations between the city-line and the circle-line are Westkreuz (trans.: west-cross) and Ostkreuz (trans.: east-cross) stations and the transfer stations between the north-south-line and the circle-line are Südkreuz (trans.: south-cross) and Gesundbrunnen stations. Besides the two S-Bahn tracks that are electrified with “third” rail, the viaduct of the city-line also carries two tracks for long distance and regional trains (e.g. ICE trains going to Frankfurt) going to the major railroad stations along the line (first and foremost the new Berlin “Main-Station”). These long distance tracks are electrified through an overhead power line and supply 15kV 16.7 Hz. AC that is used for the rest of the electrified German rail network.

The S-Bahn operates the following lines (see Table 1 and Figure 1):

Table 1 - S-Bahn Lines in Berlin [22]

Line	***Terminal Stations***
North-South-Line	
S1	Wannsee - Oranienburg
S2	Blankenfelde - Bernau
S25	Teltow Stadt - Henningsdorf
East-West-Line	
S3	Erkner - Spandau
S5	Straußberg Nord - Westkreuz
S7	Ahrensfelde - Potsdam Hbf
S75	Wartenberg - Spandau
Circle-Line	
S41	full ring - clockwise
S42	full ring - counter clockwise
S46	Königs Wusterhausen - Westend
S47	Spindlersfeld - Südkreuz
S8	Zeuthen/Grünau - Birkenwerder
S9	Flughafen Berlin-Schönefeld - Pankow

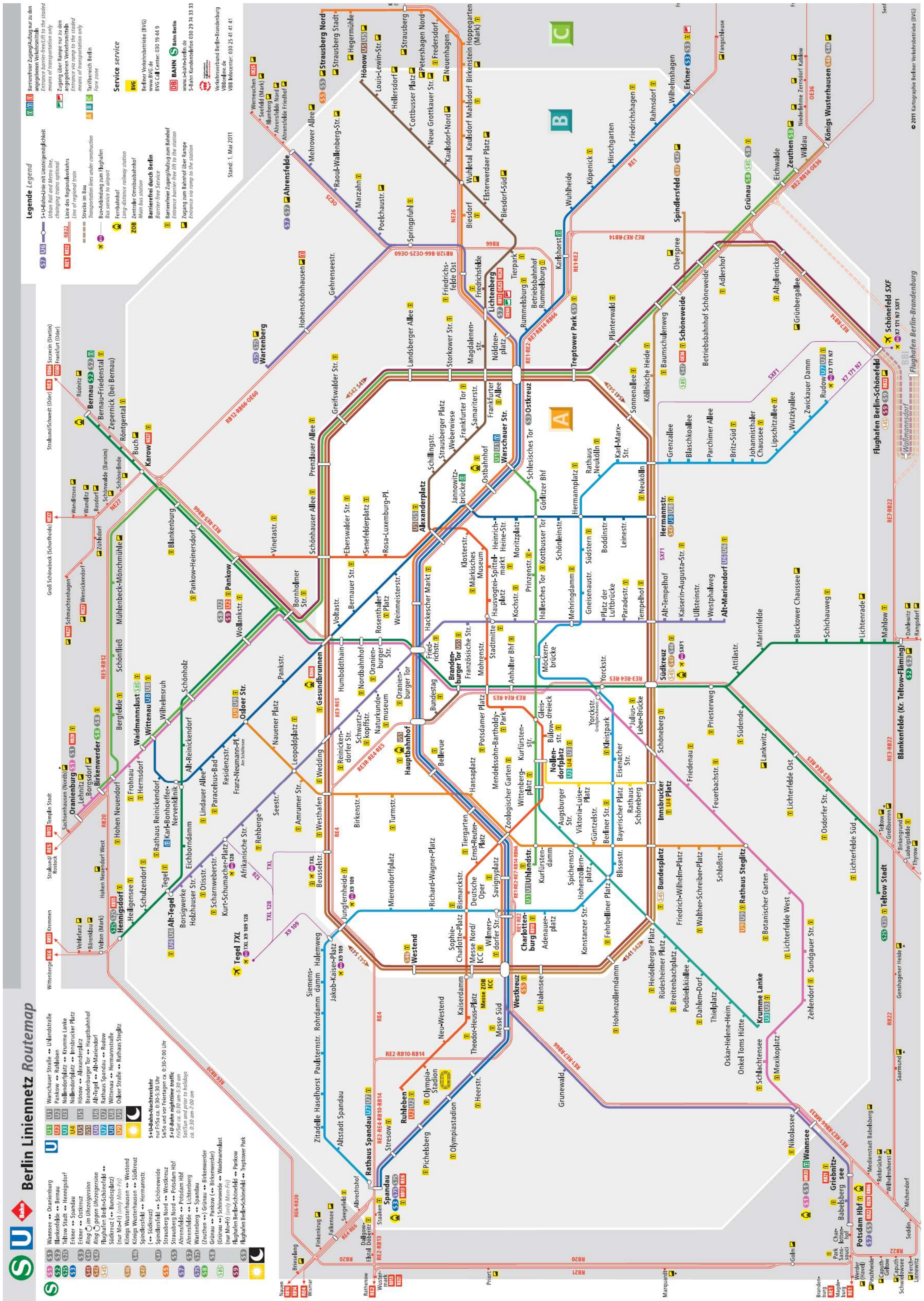

Figure 1 - U-Bahn and S-Bahn Network in the Berlin Region [23]

3.1.2 U-Bahn Berlin

History

In February 1902, the first subway line in Berlin opened. Despite running on viaducts above ground, this line set the cornerstone of the subway system. Werner von Siemens (founder of the German company "Siemens") was given permission from the king to establish an electrically operated new system that would have a higher capacity than the existing streetcars and was therefore able to increase mobility in a city that was spreading out and getting more inhabitants every year.

Despite heavy destruction in World War II, the subway was able to resume operation only twelve days after the German surrender; the last of the war damage was removed by 1951. Much more long lasting were the effects caused by the construction of the Berlin Wall. The lines connecting the east and west were cut and separated into different lines (U1 and U2) and the western lines crossing a small section of the eastern territory (U6 and U8) had to pass through the stations in East Berlin without stopping at the so-called "ghost stations." The only transfer point in East Berlin was the Friedrichstraße station, which was divided into two parts allowing riders from West Berlin to transfer into the S-Bahn going westward.

Service at previously omitted stations in East Berlin was resumed after the fall of the Berlin Wall and one by one the divided lines were reconnected allowing continuing service from east to west. The last and most remarkable extension of the network took place in 2009 with the opening of the new line U55. The new line connects Berlin's new main train station to the S-Bahn station at the Brandenburg Gate and construction is continuing for the U55 to be extended through the heart of historic Berlin and to be united with line U5 at Alexanderplatz. [24, 25]

Network

Due to evolving new technology and a changing envelope of the subway cars during different construction periods, the network of the U-Bahn Berlin is divided into a "small profile" and a "large profile" network. The older lines (U1, U2, U3 and U4) are using the smaller envelope cars and an electric track that is designed differently compared to the large profile network that is used by the lines U5, U55, U6, U7, U8 and U9. Trains cannot operate on both systems; therefore, the networks are separated, with each even having different maintenance facilities. [26]

Today's subway network in Berlin consists of 10 lines that generally do not reach as far into the suburbs as the S-Bahn does (See Figure 1). All of the lines either terminate or at least pass the city center that is encircled by the S-Bahn Ring. The lines U1, U4 and U55 do not leave the S-Bahn Ring, while lines U3, U5 and U8 originate in the city center and reach outside the S-Bahn Ring. The remaining lines U2, U6, U7 and U9 have both of their terminal stations outside of the S-Bahn Ring and connect through the city center. The lines are interconnected with the S-Bahn and with the streetcars and buses in many locations. Because of all these interconnections, the network has relatively small gaps in between the lines and many locations can be reached very easily from any given point. [23]

3.1.3 Berlin Streetcar

History

Streetcar operation in Berlin started in June 1865 with a horse-powered line in the heart of the city connecting the Brandenburg Gate to the neighborhood Charlottenburg in western Berlin. The system expanded in the following years, and in 1881 the first electric streetcar system invented and developed by Werner von Siemens was implemented in Berlin-Lichterfelde. All streetcar lines soon switched to the electric system and the system expanded further, especially following the growing demand in the economic upturn in the pre-World War I era.

In 1929, desiring increased economic efficiency during a long depression in post war Germany, the City of Berlin united the city-owned U-Bahn, streetcar and bus services in one company, creating the “Berliner-Verkehrs-Aktiengesellschaft” the predecessor of today’s BVG.

Heavily damaged in World War II and divided into two different companies, the streetcar system was facing two different transportation policies in West and East Berlin. While the East started investing in the expansion and modernization of the network and the rolling stock, the West decided to remove the streetcar in favor of extending the city’s subway and bus networks. The last streetcar line in West-Berlin territory was terminated in 1967.

After German reunification the BVG took over the operation of the network in East Berlin and started modernizing the network including the implementation of new low floor streetcars. Since 1995 the streetcar network again reaches into the former western part of the city and more plans are underway to expand the system into the West even further (e.g. to the new main train station). [27]

Network

Today the network is still mainly located in the former eastern part of Berlin. The backbone of the system is formed by nine so-called "Metro-Tram" lines that are running on the most traveled connections. Besides the Metro-Tram lines, 13 additional tram lines are offering service to more remote destinations.

Some lines serve as radial connections from the city center to outlying neighborhoods to the east and the north of the city (e.g. M1, M6). Others serve more tangential functions in interconnecting outlying neighborhoods (e.g. M4, M13). The line M10 forms a semi circle around Berlin's former (eastern core) running within the S-Bahn circle. The main structure of the network leaves no doubt that the lines are still very focused on the eastern part of Berlin (semi circles instead of circles, lines reaching mainly into the east and north). (See Figure 2) [28]

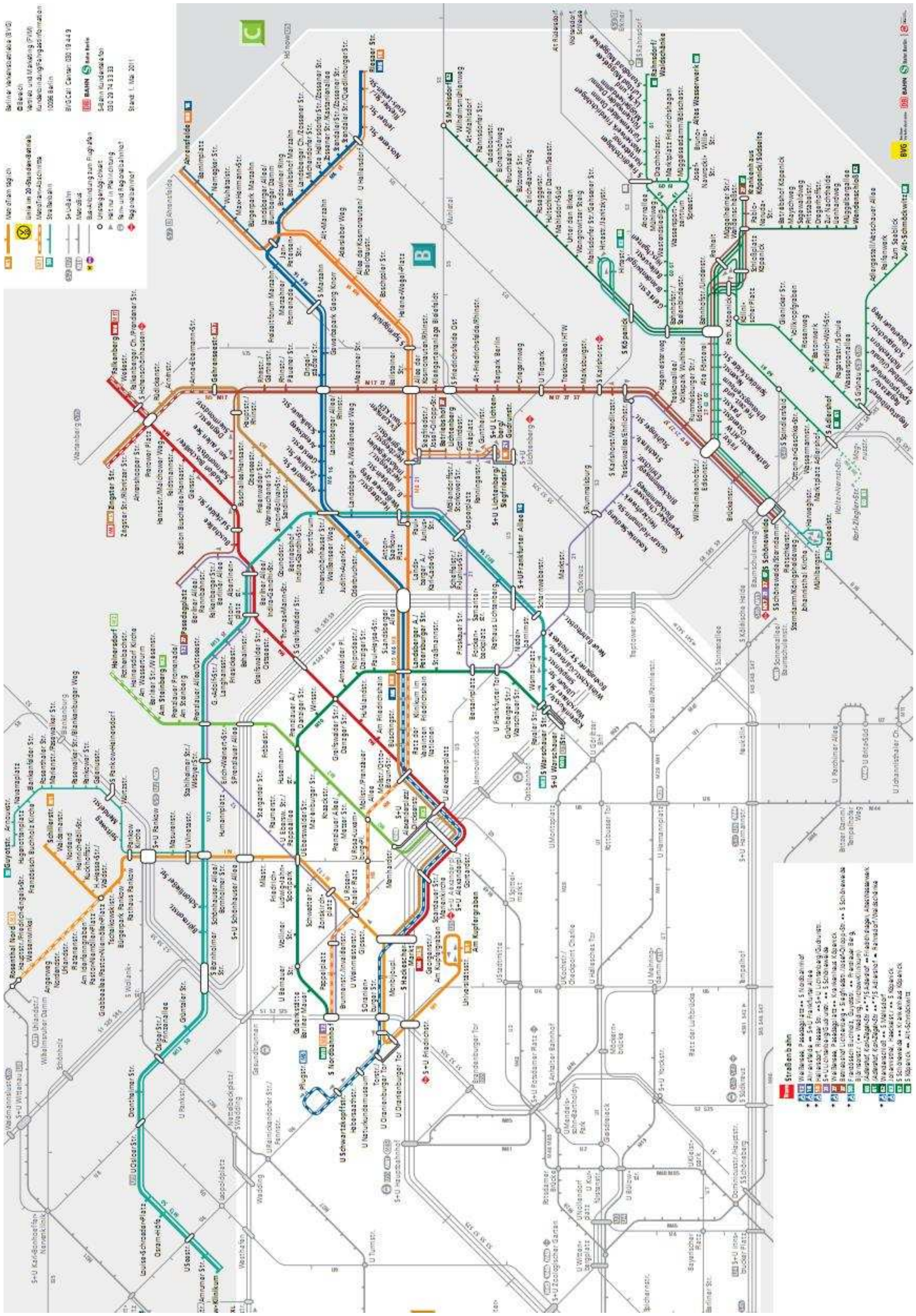

Figure 2 - Streetcar Network in the City of Berlin [23]

3.1.4 Berlin Bus

History

Similar to the first streetcars, the first bus lines in Berlin were horse-powered. In 1847, operation of the first five lines began and expanded quickly. The development in East and West Berlin after the division was affected by the different transport policies mentioned previously. The bus network expanded further in the western part of the city because it had to work as a feeder system for the U-Bahn and S-Bahn lines, a function that was mainly fulfilled by the streetcar in East Berlin. [29]

Network

Today the BVG operates an extensive network all over the city. Metro and Express Bus lines cover the areas of the city that are not very well served by the S-Bahn, U-Bahn or Tram such as, for example, the connection from the city center to the airport Berlin-Tegel. The local bus lines serve mainly as feeders for the rail systems and terminate most often at S-Bahn or U-Bahn stations. [20]

3.2 Hamburg

Hamburg, Germany's second most populous city, is located close to the North Sea at the Elbe River, which is navigable for large cargo and cruise vessels up to the port of Hamburg. Like the city of Berlin, which is congruent to the state of Berlin, the city of Hamburg is also congruent to the German state of Hamburg, which is one of Germany's 16 different states. Hamburg's current population is 1,772,000 people living in an area of 755 km². [30]

The local transit agencies in the city of Hamburg and neighboring cities and counties in the states of Schleswig Holstein and Lower Saxony are organized in the Hamburger Verkehrs Verbund (HVV, transl.: Hamburg Public Transport Association). The HVV was established in 1965 to better coordinate transit efforts in the whole region and to establish a common fare structure and ticket system. [31]

The transit system in the city of Hamburg consists mainly of three different modes: the S-Bahn (a heavy rail system operated by Deutsche Bahn), the U-Bahn (Hamburg's subway system) and the city's buses (both operated by HHA, the City of Hamburg's local transit agency). Hamburg's main station and several other local rail stations in the city and the region are also served by regional trains operated by Deutsche Bahn. These that have fewer stops and travel far beyond the city's limits. (These services are not included in this analysis because they are not regarded as urban transit.) There is also a considerable transit service offered by ferries in the port of Hamburg.

Another system in the Hamburg Region that has not been included in this analysis is the AKN system (Eisenbahn Altona-Kaltenkirchen-Neumünster) that operates three lines connecting to the U-Bahn, S-Bahn and the regional trains at three peripheral stations. Although part of the HVV, this system mostly operates outside of the Greater Hamburg Region and resembles more of a regional train service than that of a city transit system. [32]

3.2.1 S-Bahn Hamburg

History

Just like in Berlin the need for local rail connections in Hamburg originated with the need to connect railroad stations in different parts of the city. The first local train service in the city of Hamburg was opened in 1866 connecting the railroad station offering long distance rail service to Kiel with the railroad station offering long distance rail service to Berlin. [33] In 1907, the electrification of the S-Bahn network was begun and was completed in 1955. The trains were originally powered exclusively by an electric third rail carrying a 1.2 kilovolt direct current. Since 2007, the S-Bahn also operates on tracks owned by Deutsche Bahn (to the city of Stade) that are electrified with the usual German rail power system (15kV, 16.7 Hz alternating current). In order to operate under these two different systems multi-system-engines were placed in service and are now operating between Hamburg and Stade. [34]

Another remarkable event in the extension of the S-Bahn system took place in 1983 when the S-Bahn reached the southern shore of the Elbe River reaching into a part of Hamburg that had been cut off from the rest of the city by the river and the harbor lying in between.

In 1997 the company “S-Bahn Hamburg GmbH” (syn.: Limited) was formed to unite the local rail activities in Hamburg operated by Deutsche Bahn. The “S-Bahn Hamburg GmbH” is owned and operated by Deutsche Bahn. The most recent extensions of the system included the connection to Stade and to Hamburg's International Airport. [33]

Network

The network of the S-Bahn Hamburg currently consists of six lines connecting neighborhoods in Hamburg and outlying communities (see Figure 3). The S-Bahn trains go through the central city on two different routes, a northern route which bypasses the old city center and a southern route running in a tunnel directly underneath the old city center. All lines stop at Hamburg's main train station, which is located directly at the northeast corner of the city center.

Two lines (the S3 and S31) connect the city center with the neighborhoods and suburbs on the southern shore of the Elbe River such as the neighborhoods of Wilhelmsburg and Harburg and their neighboring cities in Lower Saxony. The S2 and S21 connect the eastern parts of the city and neighboring communities to the western parts of the city and neighboring communities, while the S1 and S11 connect the city's west to the north where the airport is located. [35, 36]

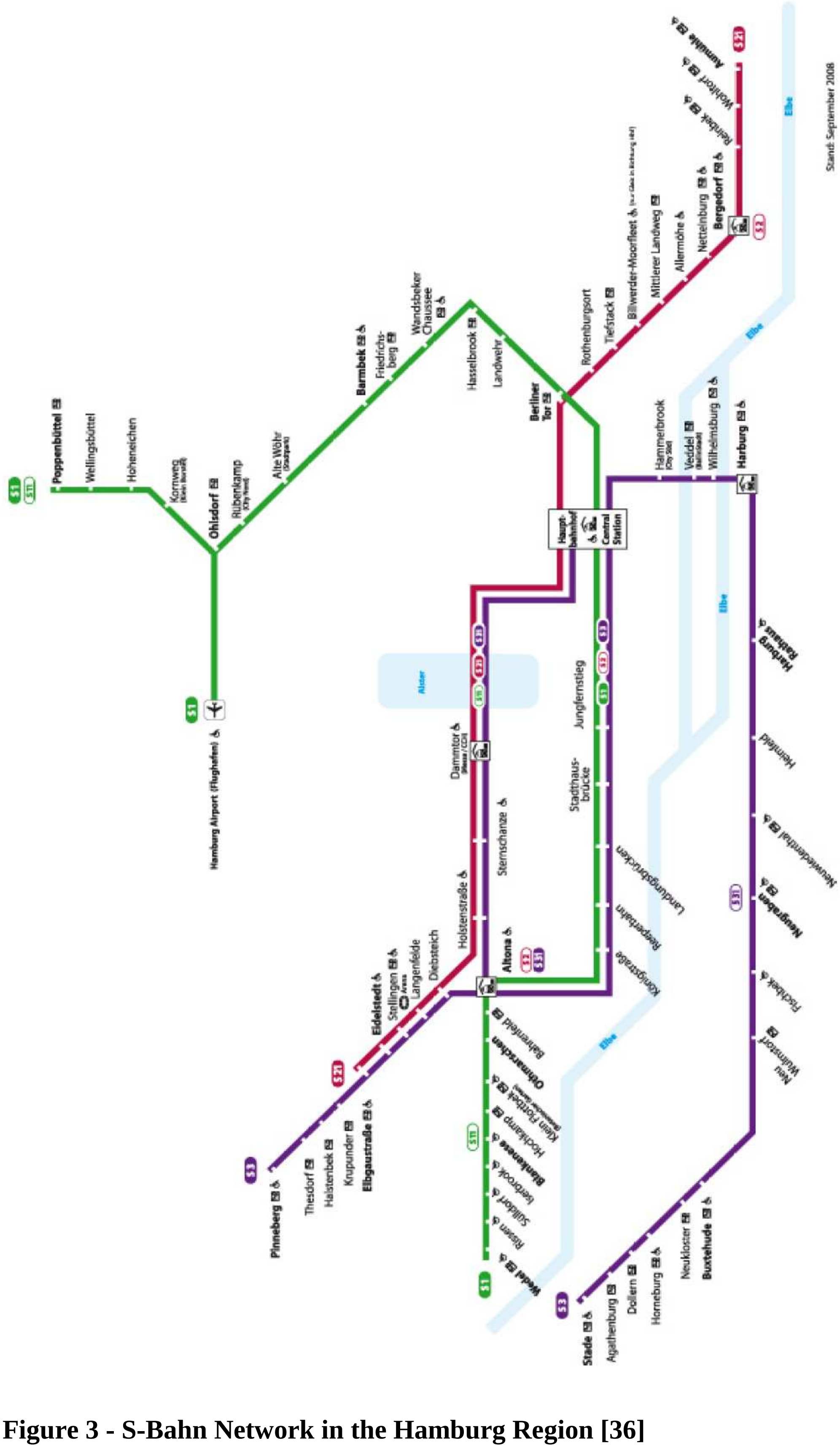

Figure 3 - S-Bahn Network in the Hamburg Region [36]

3.2.2 Hochbahn Hamburg

History

Due to a growing population and increased inner city transportation needs in the late 1800s, Hamburg officials decided to build an underground and elevated railway in the city center. Construction of the first rail segment by the companies of Siemens & Halske and AEG started in 1906. Siemens & Halske was also awarded the concession to operate the rail line and therefore founded the "Hamburger Hochbahn AG" (the Hamburg Elevated), the operating company of the subway (which has since been referred to as "Hochbahn" or Elevated [much like Chicago's 'El.']).

The first segment of the "Ring" was opened in February, 1912 and it only took until June of the same year before the full "Ring"-line connecting the major population and activity centers in the city was opened. The "Ring" connected the city hall, the northern part of the harbor and the main railroad station with the residential neighborhoods in the northern part of the city. Hugely successful, the trains and platforms soon had to be extended to accommodate more passengers. The Hochbahn AG started taking over other transit companies such as the local streetcar company and other local railroad companies. The only remaining independent companies were the S-Bahn Hamburg and the HADAG (which was and is operating barges and ferries in the harbor of Hamburg). In 1934, another subway line was opened that cut through the "Ring" in a north-south direction (today U1).

Heavily destroyed in World War II, it was a priority for city officials to restore operation quickly on the subway network to improve accessibility in the city. The network was pretty much restored by 1950. The Hochbahn AG also started new construction projects such as the extension of the U1 that was begun in 1955.

The third and last line of the subway (as of today) opened in 1973 and is called U2. The U1 and U2 have been extended several times since 1973 to reach some of the northern neighborhoods of the city that are farther from the city center.

Currently, construction is underway for the fourth line (U4) that is to connect the central Jungfernstieg Station with the newly constructed neighborhood "Hafencity" in the harbor close to the city center, which could potentially later be extended to Wilhemsburg on the southern side of the Elbe River. [37]

Network

Today, the subway network consists of three lines with the fourth line under construction. The U3 operates on the "Ring" starting at Barmbek and has a small extension into the northeast to the station Wandsbek-Gartenstadt (that is, it does not continuously circle the ring, but goes back and forth). With the Elbe River blocking extension of the city (and the subway) to the south and the relatively good coverage of the S-Bahn in the western part of the city, the U-Bahn mainly serves the northern and eastern parts of the city. The U2 operates as a diameter line through the city center connecting the northwest (Niendorf Nord) with the east of the city (Mümmelmannsberg), while the U1 operates on a loop-like connection between the north central part (Norderstedt Mitte) and the northeast of the city (Ohlstedt and Großhansdorf), connecting through the city center. The U1 also splits into two short branches at the station Volksdorf on its northeastern section. From there some trains continue to Ohlstedt, while others continue to Hansdorf. The central transfer stations in the systems are the

Jungfernstieg-Rathaus station and the Hauptbahnhof station, which also offer connections to the S-Bahn. (See Figure 4) [38]

3.2.3 Hamburg Bus

<u>History</u>

The first bus line was established by the Hochbahn AG in 1921 between the stations Schlump (Elevated) and Landwehr (S-Bahn) to allow better access for people living outside of the rail service area. In 1927, the Hochbahn took over operation of the bus network serving the cemetery of Hamburg Ohlsdorf (supposed to be the largest cemetery in the world therefore needing its own bus network).

The bus network expanded quickly especially in the years after World War II when the buses started taking over the less flexible streetcar lines. Streetcar operation was entirely terminated in 1978 in favor of the bus network, which was then reinforced with articulated buses in 1979. Since 2004, the Hochbahn is operating double articulated buses (having two joints) to cope with the high demand on the line between Burgwedel and the city center (which according to the Hochbahn is the most frequented bus line in Europe). [37]

After initial planning for a new tram network in Hamburg was pushed by the Green Party (whose participation in the local government was terminated after elections in early 2011), the newly elected mayor announced the termination of this project in favor of investment in, and extension of, the bus network. [39]

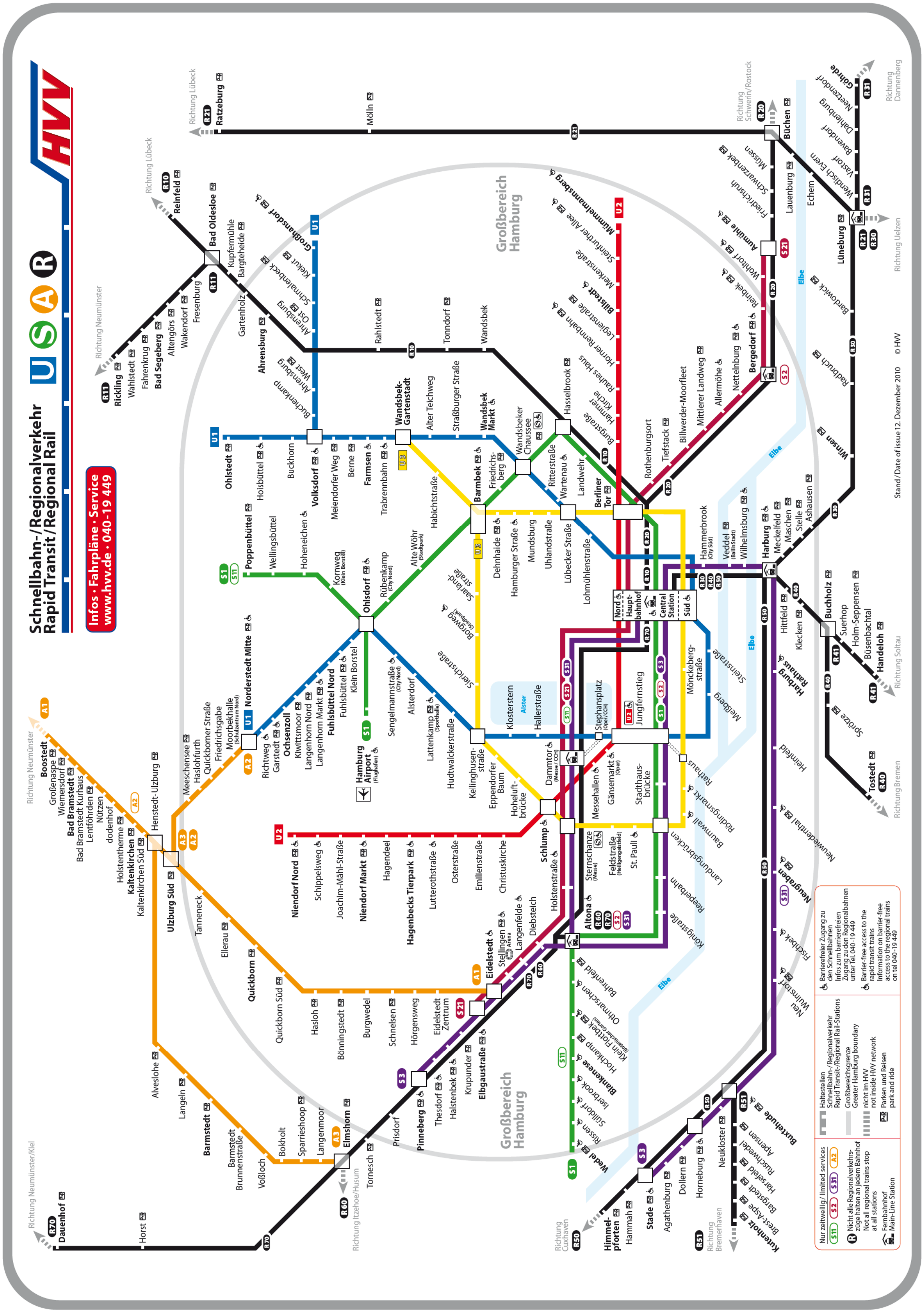

Figure 4 - S-Bahn and Hochbahn Network in and Around the City of Hamburg [38]

Network

The bus network is divided into different operational segments called MetroBus, SchnellBus (transl.: rapid bus), EilBus (transl.: rush bus), and the StadtBus (transl.: city bus).

The MetroBus network consists of 23 different lines intended to offer frequent and reliable connections to the rail network on corridors that have a high demand. The lines work as feeder lines and run between different subway and S-Bahn stations mostly in tangential routes in various distances from the core of the city (see Figure 5).

Buses operating on the SchnellBus network supplement the rail network by offering limited stop connections between neighborhoods that are not served by rail transit and the city center. Passengers have to pay an extra fee if they want to ride on one of the eight radial SchnellBus lines.

The seven EilBus lines connect big neighborhoods to rail transit stations on a one-way basis (depending on the time of day), connecting to the stations in the morning and from the stations in the afternoon and evening.

The StadtBus lines cover all remaining areas that are neither served by rail transit nor by the Metro- Eil- or SchnellBus lines. These lines that have smaller station spacing than the other bus lines usually connecting to the closest MetroBus or rail station. [40]

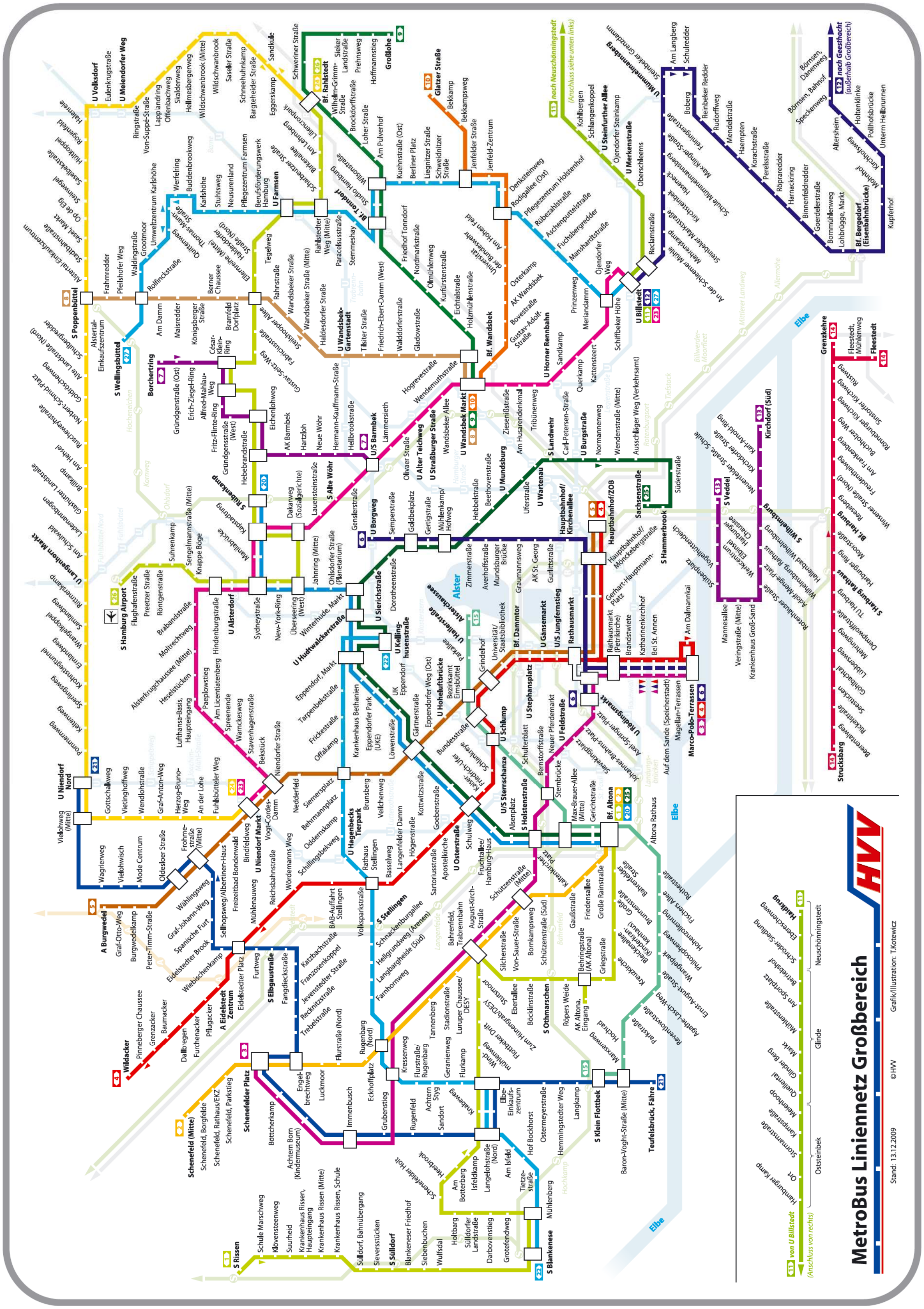

Figure 5 - Metro Bus Network in the City of Hamburg [40]

3.3 Munich

The capital of the southern German state of Bavaria, Munich is the third most populous city in Germany. About 1,317,000 people live in the relatively small area of 310 km² giving Munich one of the highest population densities in the country. [41]

Transit in the Munich region is organized under the Münchner Verkehrs- und Tarifverbund (MVV, transl.: Transport and Ticketing Association of Munich), which was founded in 1971, shortly before the opening of a new subway system. It has been regulating common fares and coordinated schedules for the whole region ever since. [42] The network in the city of Munich consists of the U-Bahn Munich (the city's subway), the Tram (a streetcar system) and the city's buses that are all operated by the "Münchener Verkehrsgesellschaft" (trans.: Transportation Company of Munich). The S-Bahn Munich (the region's commuter rail) together with some regional rail lines and the regional buses ensure connections to other parts of the region and the state. Because of the nature of the S-Bahn Munich with its good connections inside the city of Munich and frequent stops underneath the city's center (e.g. at Karlsplatz and Marienplatz), it is regarded as urban transit in this study and has been included in the analysis. The S-Bahn Munich is operated by DB Regio, the regional subsidiary of Deutsche Bahn.

3.3.1 S-Bahn Munich

History

Although the planning for a rapid train system in the region around Munich reaches back into the first half of the 20th century, the S-Bahn was completely built after World War II. The decision to build a new underground rail line connecting two dead-end railroad stations that were lying at both ends of the city was made in 1965, only one year before Munich was selected to host the 20th Summer Olympic Games, which were held in the city in 1972. The construction of the new connecting tunnel and the upgrading of the existing tracks in the suburbs were done under a tight timetable. On April 28th, 1972, the operation of the S-Bahn started with eleven lines just in time for the opening of the Olympic Games.

After a major upgrade involving massive investment from 2001 to 2005 the S-Bahn is currently being expanded by adding a second main-line tunnel underneath the city to increase capacity. Other projects that are underway include a better connection to the city's airport and an extension of line S7 into Geretsried. [43]

Network

The network of the S-Bahn Munich is centered around the underground main line that connects the main station (Hauptbahnhof) in the west with the Ostbahnhof east of the city (see Figure 6). All lines except for S20, S27 and A pass through the tunnel and continue until Donnersbergerbrücke in the west before they start to split in different directions. The lines S1 and S8 meet at the airport and close a circle around the northern part of the city, while the lines S20 and S27 bypass the city center in the south without using the main line tunnel. The S-Bahn lines S1 through S8 connect to the city center and extend far into the suburbs before they reach their terminal stop and turn around. A special function is fulfilled by line A, which just works as a feeder for the S2 in Dachau. [44, 45]

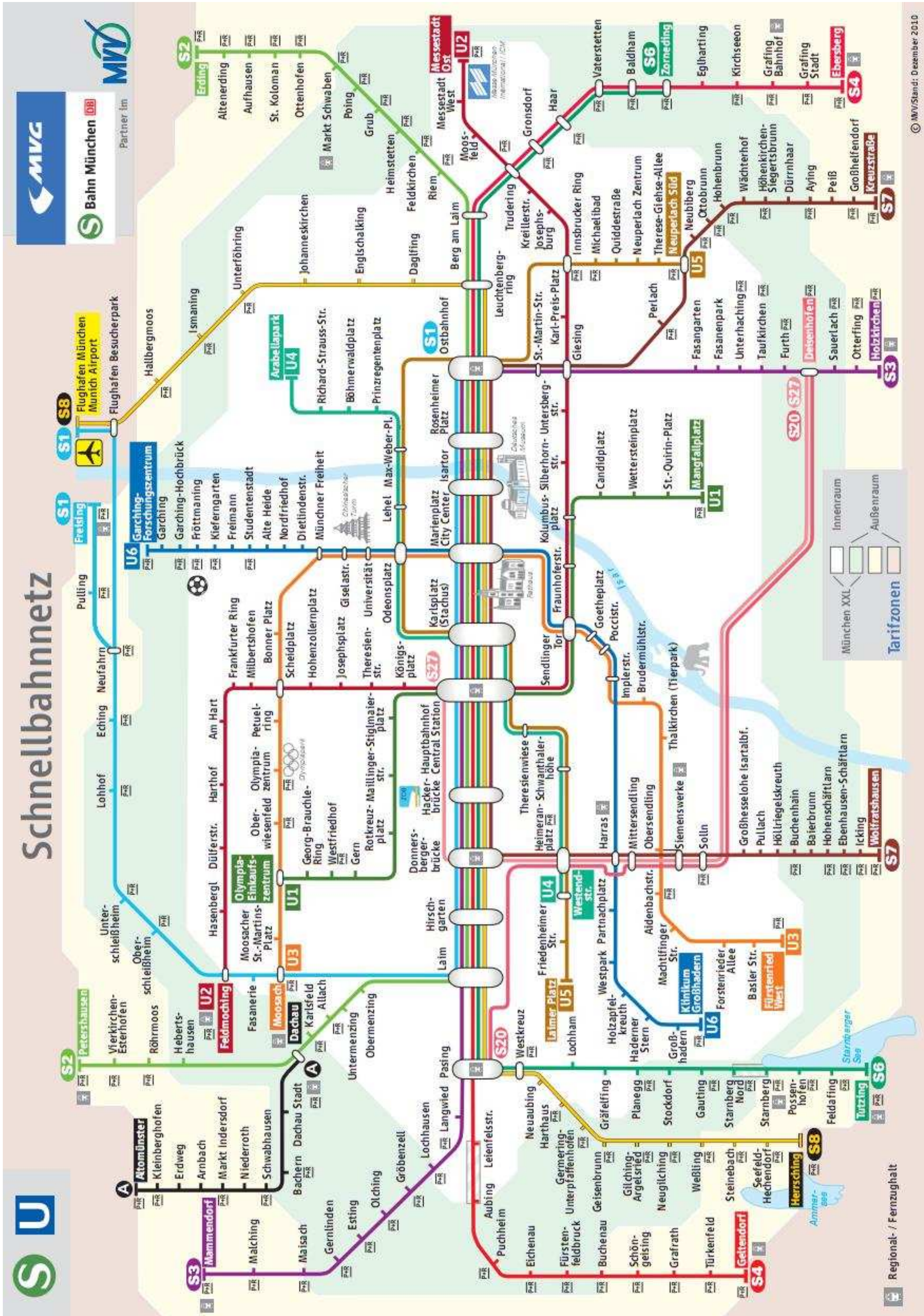

Figure 6 - Munich's Rapid Rail Network (S-Bahn and U-Bahn) [44]

3.3.2 U-Bahn Munich

History

In 1959, the Munich city council decided to place streetcar operations in the north-south direction into a tunnel under the city center. The city wanted to create a light rail system with mixed subsurface and streetcar operation like the one implemented in Brussels, Belgium. Instead of creating a mixed operation, the city council decided in 1964 to use the proposed north-south line for subway operation. After the 1965 announcement that Munich would host the 1972 Olympic Games, the council decided to build another subway line to improve connectivity to the sports venues of the Games. Operation of the subway started in 1971. In the following years the network kept expanding existing lines and adding new lines. A third line was opened in 1980 followed by three more lines by 1993. The proposed expansion of the system is not yet completed and line expansions have been opened in recent years such as the expansion of the U3 from the “Olympiazentrum” station to the “Moosach” station. [46]

Network

As mentioned above, the subway network started from a single north-south line, which today is the U6. The U3 was opened as the so called “Olympia Linie” (trans.: Olympic Line) and shares much of its alignment with the U6. Because the S-Bahn with its predominant east-west alignment serves as the major east-west connection between the outlying areas to the city center, the U-Bahn mainly connects the central areas north and south of the S-Bahn main line to the transit network. Most of the lines run diagonally and connect to the S-Bahn main line approximately in the center of their routes (e.g. U1 and U4). The U3 forms an open loop and connects the west of the city to the S-Bahn mainline, while the U5 runs parallel to the S-Bahn mainline for a long time and connects to it twice. The U2 is the only rail line that serves the fairgrounds in the far east of the city and connects to the main rail station by running parallel to the S-Bahn mainline before it goes northwest of the city. All in all, the U-Bahn lines mainly serve as quick connections to the city center and the S-Bahn, and for short range connections within the central city. [44]

3.3.3 Munich Streetcar

History

Horse-powered streetcar operation in the city of Munich started on September 21, 1876. Until then only horse carts provided public transportation service in Munich. Operation was performed by a private company that transferred one percent of its gross revenue to the city for the use of public street land. The first streetcar line connected the main railroad station, the city center and a few stations. Like many German cities, Munich expanded rapidly in the late 1800s. In 1892, the private streetcar company did not have enough funds to support necessary system expansion of the streetcar network so the City provided funding for new lines and for the electrification of the existing lines. The first electrified line finally started operation on June 23, 1895, and in 1900 the electrification was complete. In 1907, the City took over the streetcar service after the private company continued to lose revenues over several years. The tram kept expanding in subsequent years.

Although heavily destroyed in World War II, the streetcar resumed operation four weeks after the end of the war. Large parts of the network had been destroyed and had to be rebuilt in a major effort that lasted until 1950. Although many buses were put into operation in this era the streetcar network kept on expanding to meet the transportation demand of a growing city. In 1964, the streetcar system reached it greatest extent (135 km or 84 mi). After the implementation of the subway and the S-Bahn the streetcar system was cut back piece by piece until the city council decided in 1984 to maintain a strong streetcar network to fill in the gaps between the other rail systems. As a result of this decision even closed lines were put back into operation. Low-floor trams started operation in 1991 to improve accessibility for persons with disabilities. Today almost all of the streetcars are low-floor cars. [46]

Network

Today, the streetcar lines mainly operate as local connections within the city and as a feeder system for the rapid train networks (see Figure 7). This probably becomes most clear with the example of streetcar line 23 that is not even operationally connected to the other streetcar lines. At its southern end it terminates at the “Münchener Freiheit” U-Bahn station. Other lines such as streetcar lines 17, 18, 19 in the east-west direction and 27 in the north-south direction travel a significant distance as diameter lines crossing the city center and connecting neighborhoods not served by the U-Bahn to the city center and to the rapid transit lines. Lines 16, 20 and 21 end in the city center coming from the northwest of the city, while the lines 12, 15 and 25 pass around the city center serving more as radial connections. [47]

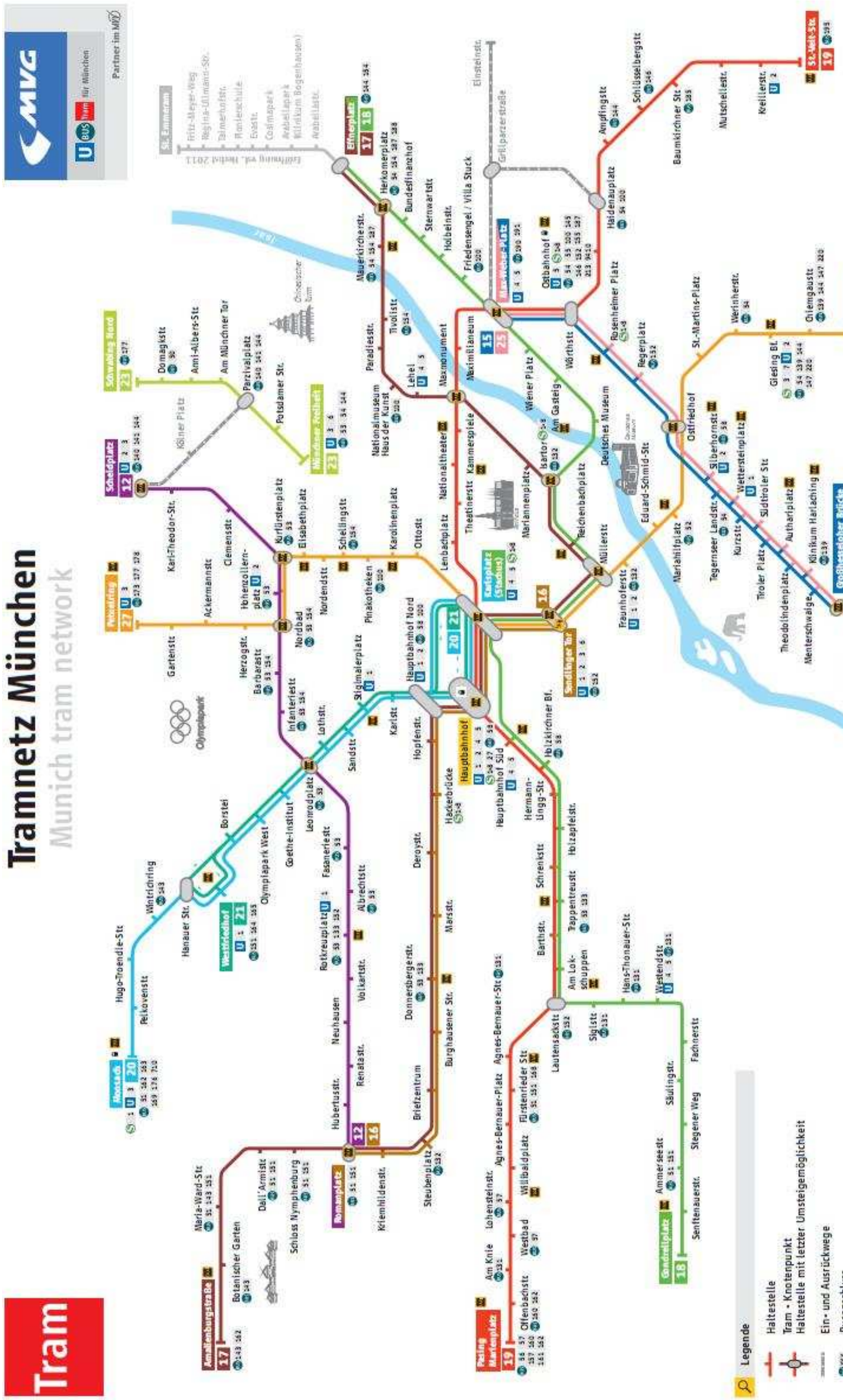

Figure 7 - Streetcar Network in the City of Munich [47]

3.3.4 Munich Bus

History

The first bus company in Munich started its operation in 1897. Although several bus lines were initiated in the following years none of these lines existed after 1910 because of the relatively bad service with noisy and uncomfortable vehicles that could not compete with the streetcar's comfort. Bus operation resumed in 1919 when the postal service of the German Empire started operation of new bus lines in order to relieve the overcrowded streetcars. In 1934, the City of Munich started its own bus operation for the same reasons.

A population boom and economic recovery in the post war era resulted in an explosion of traffic volumes to which the City responded by putting more and more bus lines into operation because they were cheaper, more flexible and faster operationally than streetcars. The bus network grew further and for a time buses were designated to take over streetcar operation. In 1987, the first low-floor buses were put into operation.

The most recent radical change in the structure of the bus network took place in 2004 with the division of the bus network into MetroBuses and CityBuses. [46]

Network

The bus system in Munich is divided into a MetroBus network (lines 50-60) (see Figure 8) and a StadtBus (trans.: CityBus) network (lines 100-199). While the local StadtBus buses connect almost every part of the city to either the streetcar or one of the rapid rail lines, the MetroBus buses serve more as collector lines with shorter headways that serve radial lines around the city (e.g., lines 50 in the north and 54 in the south).

Together the 66 bus lines fill in the gaps between the three rail networks to offer transit service to the less densely populated areas of Munich. [48]

3.4 Hanover

Situated in the middle of northern Germany, the city of Hanover (German: Hannover) is the capital of the German state of Lower Saxony. With a total population of 519,212 living in an area of 204 km² [50], Hanover is the most populous city in Lower Saxony and it is the 11th most populous city in Germany.[30] The city of Hanover is part of the “Region Hannover,” which replaces the county level in the region around Hanover and is also responsible for the ordering and funding of regional transit service in the region on behalf of the State of Lower Saxony. [51]

Transit efforts in the region around Hanover are coordinated by the GVH (Großraum-Verkehr Hannover, transl.: Greater Hanover Transportation), which was founded in 1970 and unites the transit services of the local transit agencies while also providing a common fare system. [52]

Transit services in the city of Hanover are offered by the “Üstra Hannoversche Verkehrbetriebe AG” (transl.: Hanover Transit Agency), which operates the light-rail and the local bus network. [53]

Heavy rail S-Bahn service between different rail stations in the city and the region is offered by Deutsche Bahn and is summarized under the Brand “S-Bahn Hannover.” Deutsche Bahn and the “Metronom Eisenbahngesellschaft,” which operate other local trains beside the S-Bahn that serve major railroad stations in Hanover, have not been integrated into the S-Bahn brand. All of these longer range regional trains (such as the

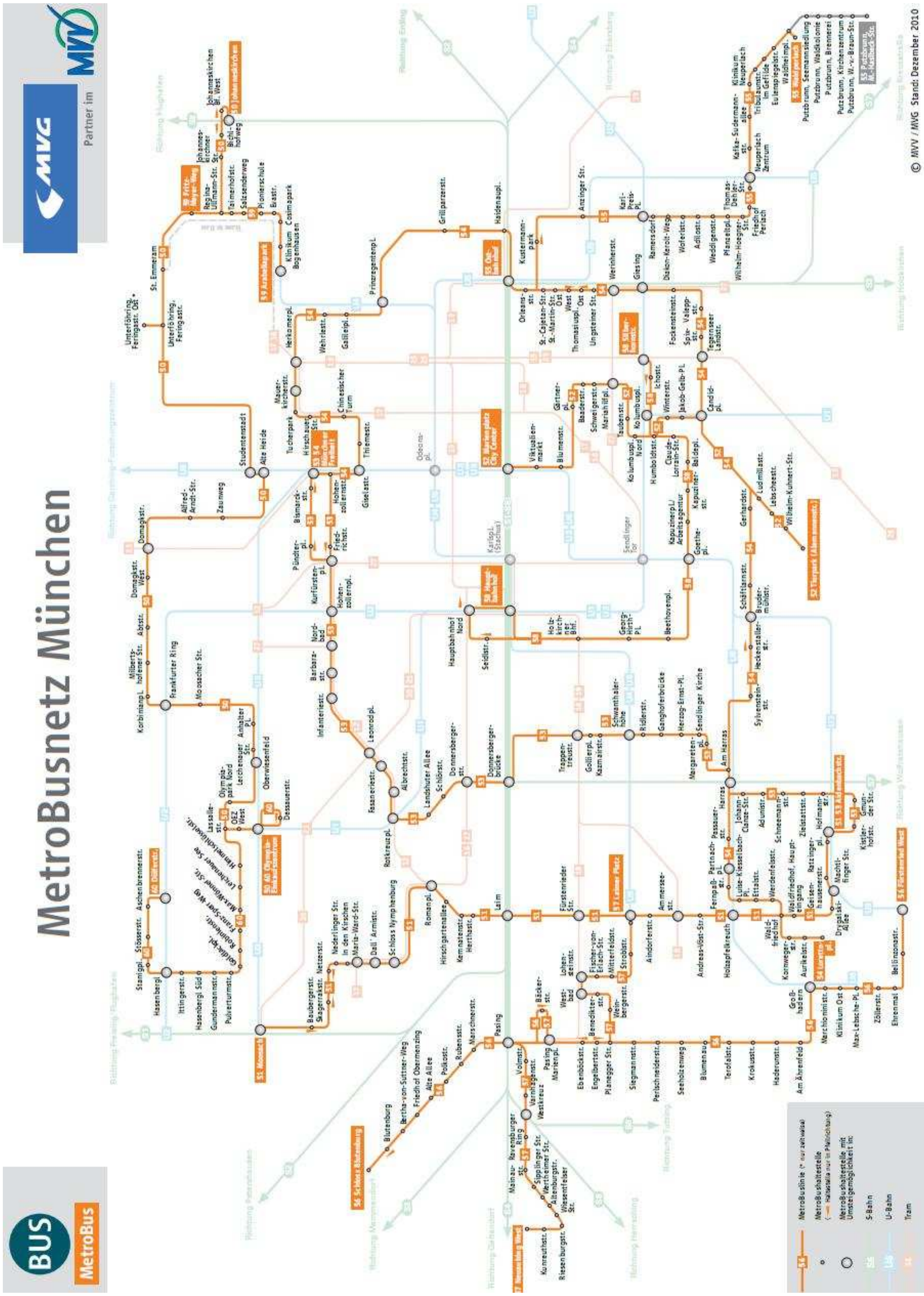

Figure 8 - MetroBus Network in the City of Munich [49]

connection to Brunswick) leave the Hanover region for large portions of their voyage and thus are not included in this analysis.

Regional bus service that supplements the S-Bahn and regional train service is offered by the “RegioBus Hannover GmbH”. Some of the regional buses also serve the city of Hanover, but their main purpose is the connection of outlying communities to the rail lines. [54] Because of its focus on the outlying parts of the Hanover region the RegioBus is not included in this analysis.

3.4.1 S-Bahn Hanover

History

Plans for a local train system in and around Hanover have been around since the 1960s. They did not become reality until 1989 when the so called City Bahn was opened, which for the first time operated on an hourly schedule and also offered additional trains during the rush hours on 30 minute headways. The City Bahn network was planned to be upgraded and extended in the future.

In 1990, Hanover was awarded the 2000 World Exposition (Expo). For this event and the many expected visitors from all over the world, the entire transportation network in the region and in the city was upgraded and extended. These efforts included the creation of the “S-Bahn Hannover” brand, which took over the City Bahn lines and other local trains. Tracks were added, upgraded and electrified to accommodate higher speeds; stations were set to a higher standard of safety; and new rail cars were bought that met the highest comfort standards. As a part of the network extension, Hanover’s international airport got its first rail access served by the S-Bahn. S-Bahn operation started on May 28, 2000 on a preliminary network just in time for the opening of the

Expo. Initially, all lines ended at the fairground station to serve the Expo. Regular operation on a network consisting of five lines was started on November 5, 2000 after the exposition was over.

In 2008, the S-Bahn was extended to Hildesheim and Celle and is now serving seven different lines. An eighth line is put into operation for large fairs and events only. [55]

Network

The S-Bahn network consists of seven lines that all meet at Hanover's main railroad station, the main transfer point between the lines and which also offers transfers to regional, long distance and high-speed trains to all other parts of the country (see Figure 9). Lines S1 and S2 serve the western part of the Hanover region. Both lines start in the west, serve Hanover's main station and then return to the west. The S1 line even serves the station in Haste twice on its loop. The northwest and the southwest are served by the S5 that operates between Hanover's airport and the city of Paderborn (in the neighboring state of North Rhine Westphalia). The S8, which runs between the airport and the city's fairgrounds, is only in operation during big fairs and events.

Serving the north and the southeast is the S4, which operates between Bennemühlen and Hildesheim. Hildesheim is also served via Lehrte by the S3 that terminates in Hanover's main station. The remaining lines S6 and S7 run between the main station and the city of Celle in the northeast of Hanover, with the S6 taking a shortcut by not running through Lehrte as the S7 does. On the S4 and S5 routes additional trains are run only on a part of the line to reduce headways for these connections. On the

S4 line these trains operate between Bennemühlen and the main station and on the S5 between Hameln and the airport. [56, 57]

3.4.2 Hanover Light Rail

History

The history of light rail in the city of Hanover began in 1872 when the first horse-powered streetcar line began operation. More lines were constructed shortly thereafter and the system grew over large parts of the city. After the existing lines were taken over by the "Straßenbahn Hannover Aktiengesellschaft" (which was later renamed "Überlandwerke und Straßenbahnen Hannover AG" or short: Üstra), the Üstra began electrification of the streetcar network in 1893, which was completed in 1897 (although streetcars had to be powered by accumulators in the city center at first because city officials did not like the appearance of the catenary wire). The streetcar system grew fast and expanded far beyond the city's limits such that in 1899 a streetcar line to the city of Hildesheim was opened (today served by the S-Bahn). In the same year, the Üstra started operation of freight streetcars that carried goods such as crops from the vicinity into the city and the factories. After a short decline of the network in the post war era and the termination of freight and overland traffic, the Hanover City Council in 1965 decided to build underground rail lines in the city center to reduce streetcar traffic on city streets. Construction was started later that same year.

In 1970, the "Großraum-Verkehr Hannover" was founded, a transportation association that created a common fare system and that coordinated schedules for the transit services in the region.

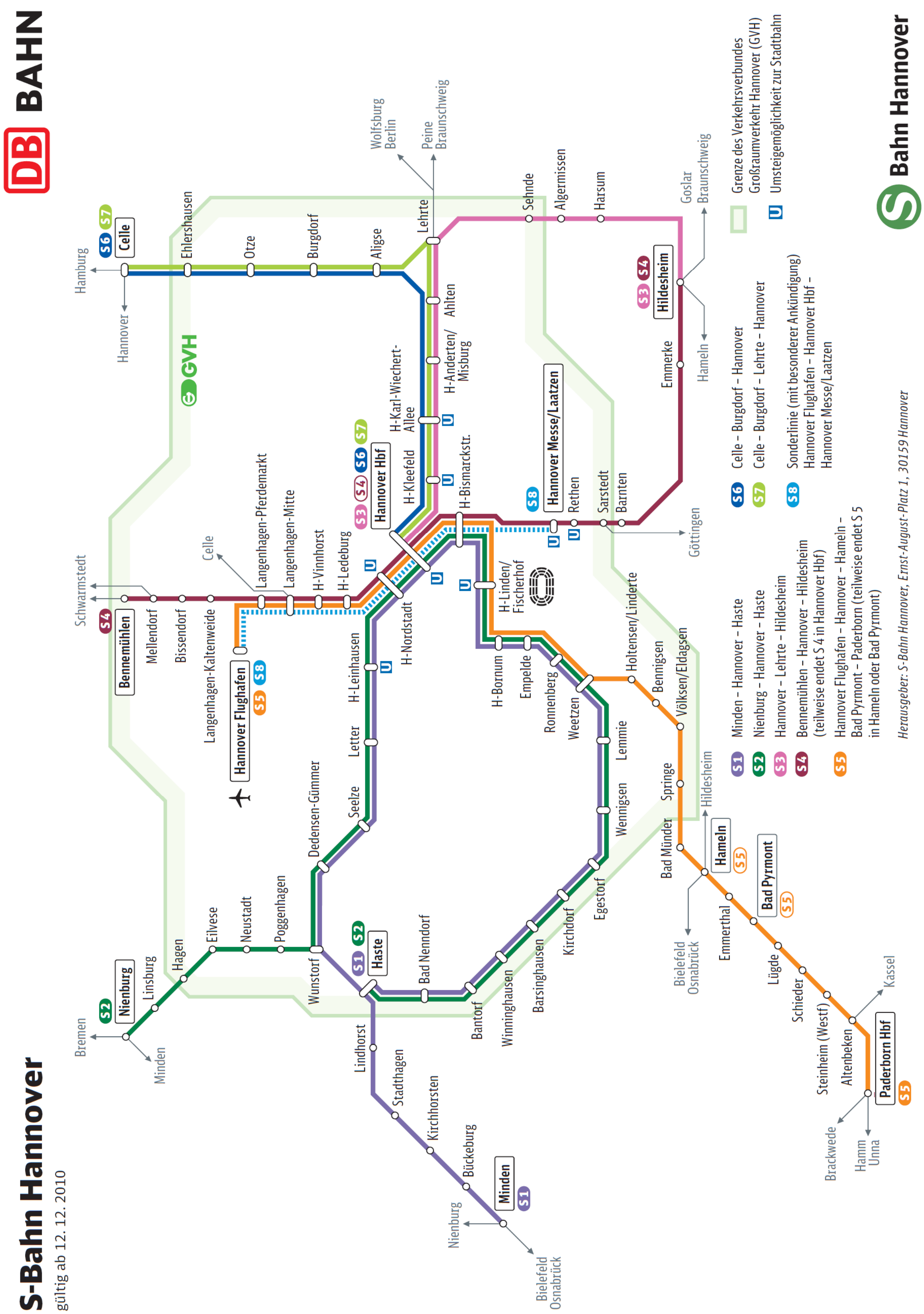

Figure 9 - S-Bahn Network in the Hanover Region [58]

The first underground light-rail line was opened in 1975 (ten years after the start of initial construction). The new rail vehicles operated at street level outside of the city center and only went underground for passage through the center. The underground system was completed in 1993 and the streetcar tracks in the city center were removed accordingly. Today only two lines still operate above ground in the city center. As of today, the light-rail system is still expanding although the extensions are usually only short additions in the suburbs. [59]

Network

The light rail network today is dominated by three main lines in tunnels underneath the city center (see Figure 10). The tunnels are named A- (Waterlooplatz - Lister Platz, blue lines), B- (Vahrenwalder Platz - Döhrener Turm, red lines) and C-tunnel (Königsworther Platz - Braunschweiger Straße, yellow lines) and allow separate operations. Because of three different separate tunnels, delays on one line are not transmitted to another line, which has huge operational advantages.

The central transfer station in the network is Kröpcke, located in the main shopping district. All underground lines stop here so that transfers to almost everywhere are possible. The red lines generally connect north and south of the city while the yellow lines connect the east of the city to the northwest. The northeast is connected to the southwest via the blue lines and the remaining streetcar line (number 10) connects some neighborhoods in the west to the city center. The above ground streetcar lines end in the city center and were originally planned to be replaced by underground service, which has not yet been built.

All underground lines that use the same tunnel in the core of the city split up in the surrounding neighborhoods to serve different destinations while allowing longer headways in the suburbs and shorter headways in the city center. During times of high demand (e.g., during fairs) lines 16 and 18 improve service on the connection between the main railroad station and the two stations Messe Ost and Messe Nord where the two entrances to the fair ground are located. [60, 61]

3.4.3 Hanover Bus

History

The first horse-powered bus line in the city of Hanover was opened in 1852 and was designed to connect the thriving southern neighboring town of Linden (today part of Hanover) with the new main rail station to the north of the city. Partly replaced by streetcar lines, the bus network always played a minor role in Hanover's city transit with the heavy load being served by streetcar/light-rail. However, buses played a major role in the replacement of the streetcar's overland lines in the 1950s. Especially on low-load lines, the operation of buses was thought to be more efficient. To improve service on the bus lines and enable access for persons with disabilities, Üstra implemented low-floor technology in its buses starting in 1993. [59]

Network

Because of the extensive light-rail network, the bus lines mainly serve as feeder lines for the light rail lines connecting the outlying neighborhoods to the rail stations (see Figure 11). The majority of the 40 lines run tangentially around the city with many

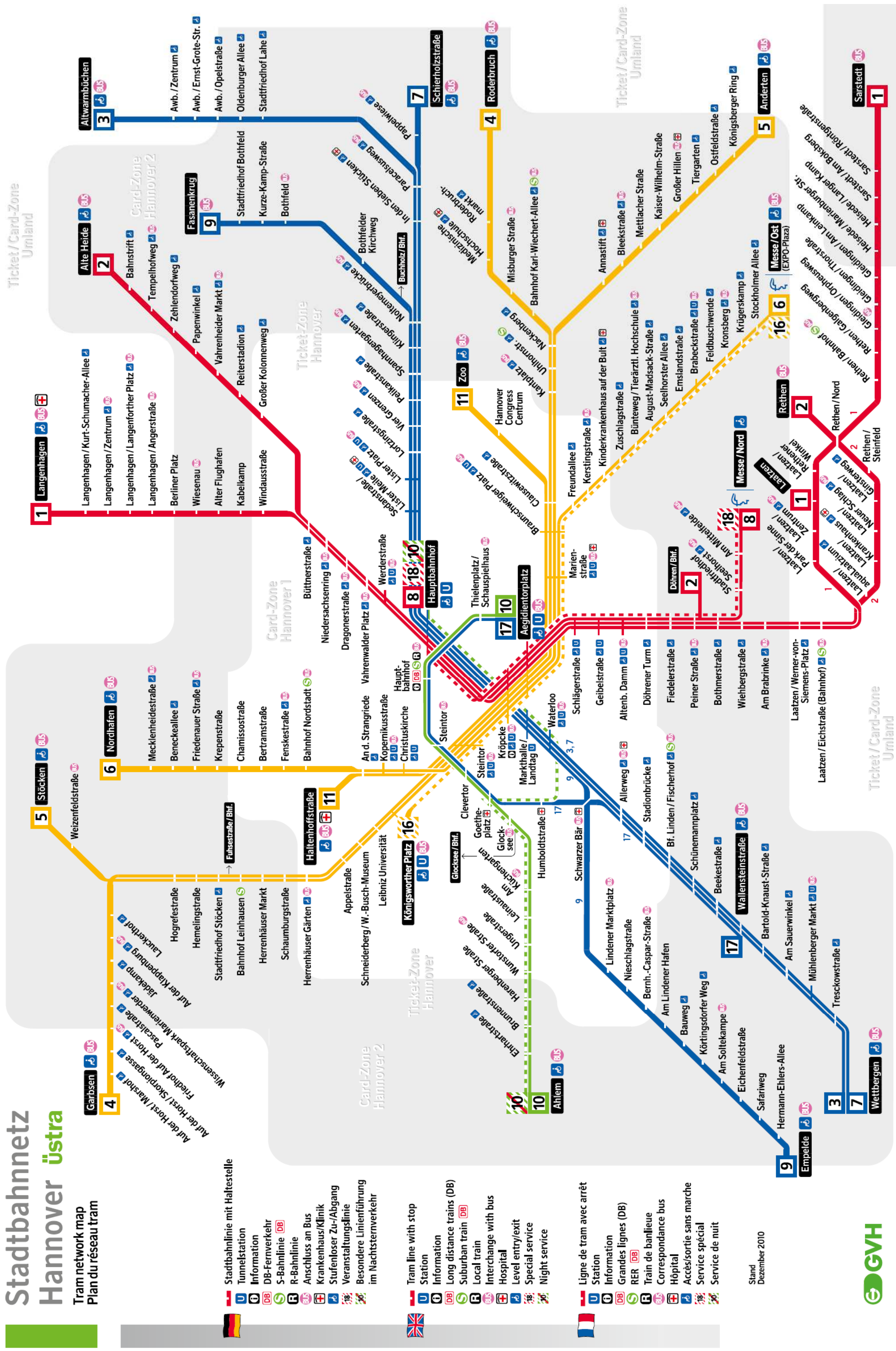

Figure 10 - Light Rail Network in the City of Hanover [60]

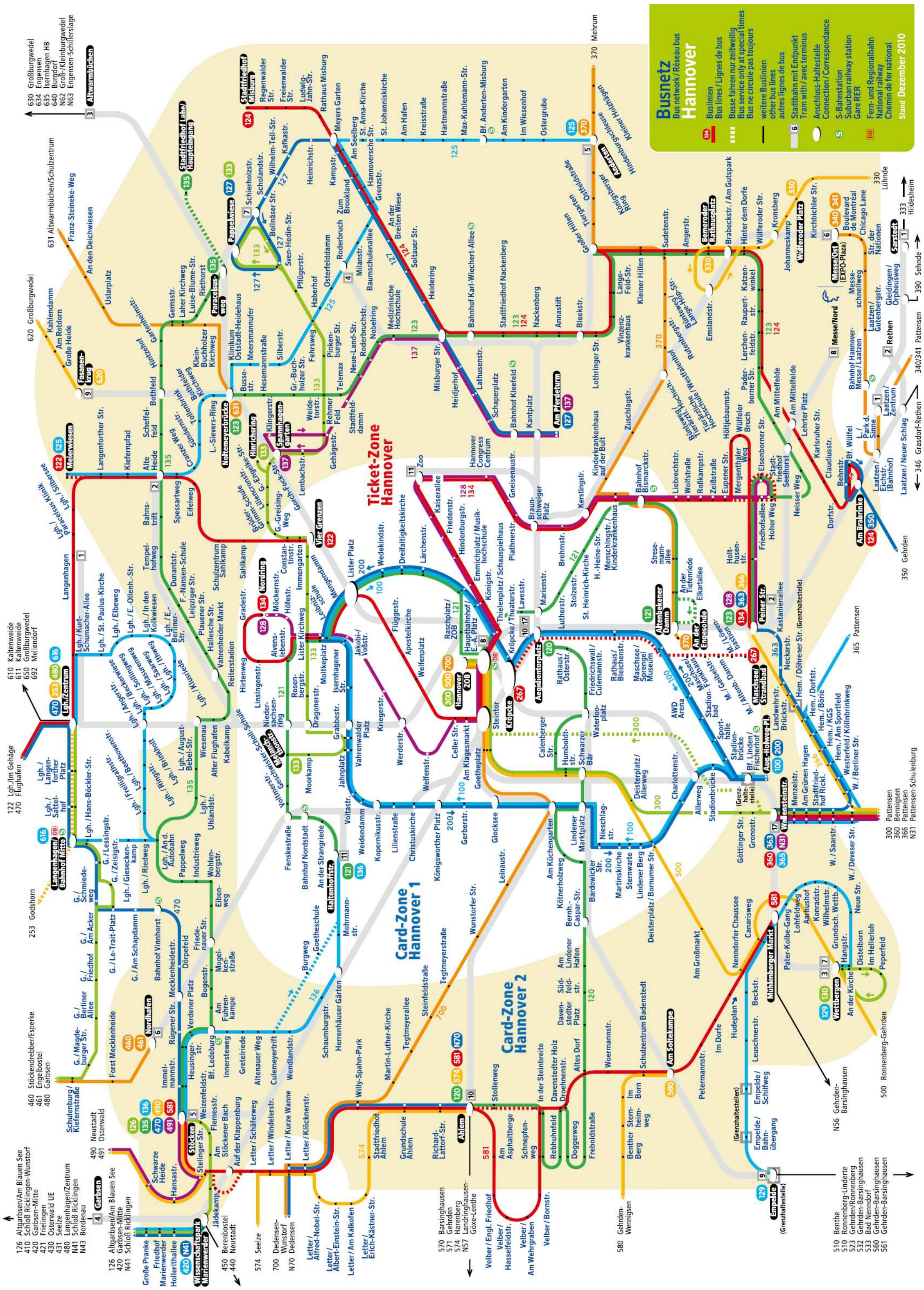

Figure 11 - Local Bus Network in the City of Hanover [62]

traveling from one light-rail station to another. Many extend beyond the city boundary and serve as extensions or a supplement for light rail lines (such as line 700). Close to the city center, a loop service is offered by lines 100 (clockwise) and 200 (counterclockwise) to serve the important function of a circle line that is not part of the light-rail network. [62, 63]

3.5 Karlsruhe

Compared to the other cities in this study, Karlsruhe is a relatively small city located in the northwestern corner of the German state of Baden-Württemberg in southwestern Germany. The city of Karlsruhe has a total area of 173.46 km² and a total population of 283,048 resulting in a population density of 1632 persons per km². [64]

Besides its castle and planned street layout, the city is famous for its urban and regional public transit. Karlsruhe is one of the few cities that operates a "mixed" two-system regional train service that operates on the railroad tracks in the region and switches to the streetcar tracks in the city center. This so called "Karlsruher Modell" has been a role model for other cities in Germany.[65] In addition to the so-called two-system "Regio-Stadtbahn" (transl.: regional-city-train) that is operated by the "Albtal Verkehrsgesellschaft" (AVG; transl.: Albtal Transportation Company), a streetcar system and a local bus system are operating in the city of Karlsruhe. The streetcar and city bus networks are operated by the "Verkehrsbetriebe Karlsruhe" (VBK; transl.: Transportation Company of Karlsruhe), an agency of the City of Karlsruhe. Deutsche Bahn with its subsidiary DB Regio also operates a set of regional trains that serve longer distances than the Stadtbahn lines. Besides the rail networks there is also a regional bus network spanning parts of the region around Karlsruhe operated by various bus companies.

Like most other German cities, the transit services in and around Karlsruhe are coordinated by a transportation association. The “Karlsruher Verkehrsverbund” (KVV; trans.: Transportation Association of Karlsruhe) unites all transit agencies in the region under one roof and offers a common fare structure so that it is possible to use all transit services with one ticket. [66]

Only the local bus and streetcar service in the city of Karlsruhe and the regional Stadtbahn’s have been included in the this research because they serve as the backbone of a heavily rail dominated transit network in the region.

3.5.1 Regio-Stadtbahn Karlsruhe

<u>History</u>

The Regio-Stadtbahn Karlsruhe began with an experiment in the late 1950s. At that time the Karlsruhe City Council and the State of Baden Württemberg had to decide how to proceed with the operation of an old narrow-gauge rail line (the so called “Albtalbahn”) that was serving several suburbs and neighboring communities south of Karlsruhe and that connected to the city’s streetcar system at a peripheral railroad station on the south side of the city. Options included shutting down rail operation in the corridor and to replace it by bus service or to regauge the line into standard gauge and connect it to Karlsruhe’s main station. In the end the city and the state decided to regauge the line and connect it to the streetcar system to allow local trains to connect directly into the city center without the riders having to transfer. In 1961, the Albtalbahn (today the southern branch of the S1) had been entirely upgraded and rail traffic into Karlsruhe was operating under the guidance of the newly created AVG. In 1979, a new innovation was introduced after a long stagnation of the development of the system. In order to expand the network of the AVG to the northwest, tracks owned by Deutsche Bahn had to be used for a short distance (today the northern branch of the S1). For the operation on both the railroad tracks and the streetcar tracks the introduction of the so-called two-system rail cars that fulfilled both the standards of the EBO and the BOStrab was necessary. With this use of federally owned railroad tracks by streetcar/Regio-Stadtbahn trains and the two-system operation, the “Karlsruher Modell” was born. The ridership on the new line exceeded ridership expectations and headways soon had to be reduced. Because of the great success the line was extended in the 1980s.

Because of the very dense rail network in the Karlsruhe region and the relatively long distance from the main station to the city center, officials of both the state and the city decided to expand the “new” system on other lines. Based on great success in increasing ridership in the system services kept expanding in the 1990s and 2000s. [67]

Network

Today, the Regio-Stadtbahn-network of the AVG stretches in all directions with the city of Karlsruhe at its center (see Figure 12). Stadtbahn-lines S1, S11, S2, S4, S5, S51 and S52 all pass through the city center of Karlsruhe using streetcar tracks. The main line used in the city is the segment between Herrenstraße and Europaplatz right in the city center. The S31, S32, S6 and S9 lines bypass the city center forming peripheral connections (S31, S32 and S9) or work as a feeder line for other lines (S6). Most of the lines extend far into the region and even into other cities such as the S1 into Bad Herrenalb (south of Karlsruhe) or the S51 and S52 into the city of Germersheim to the northwest. [68, 69]

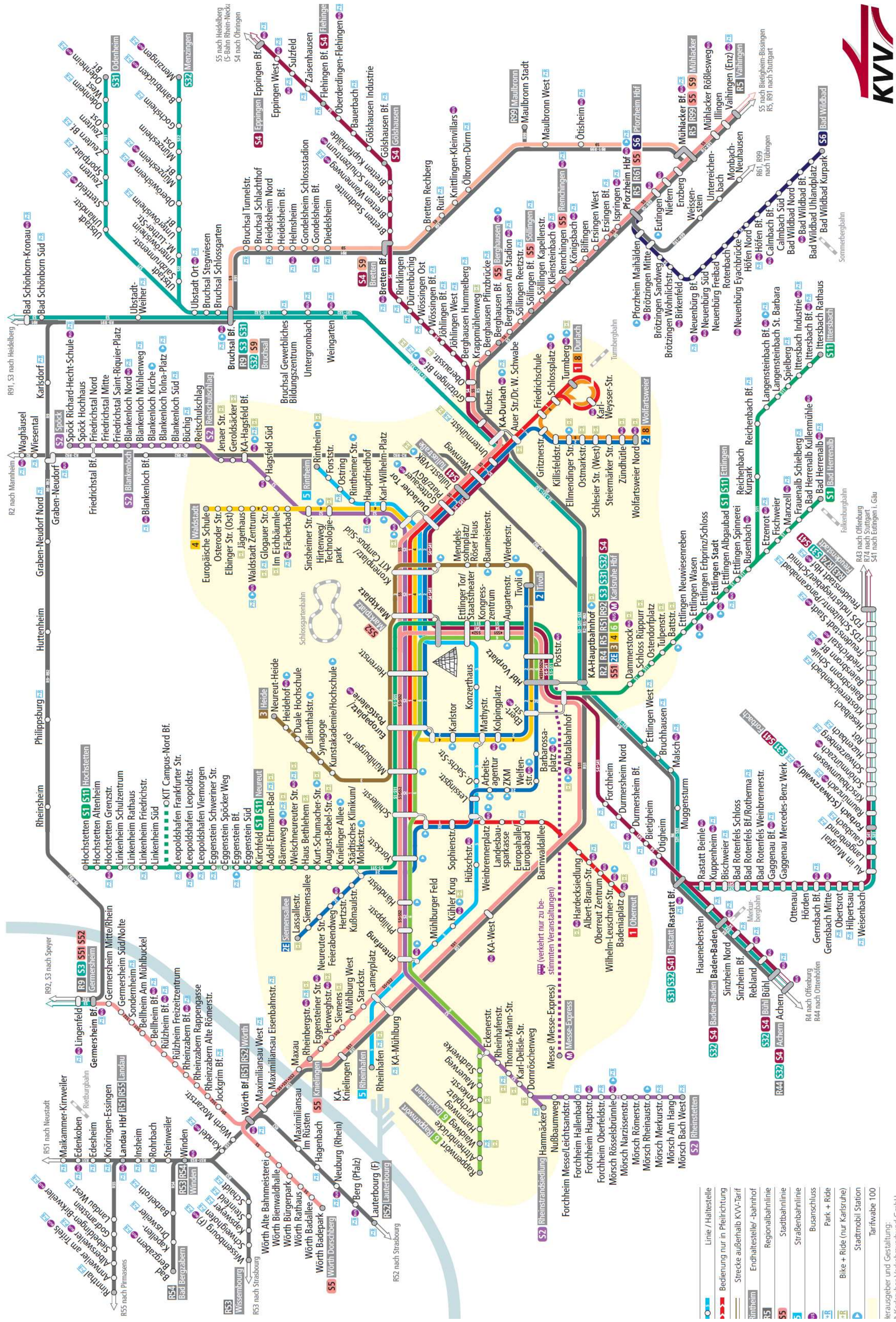

Figure 12 - Regio-Stadtbahn and Streetcar Network Around Karlsruhe [68]

3.5.2 Karlsruhe Streetcar

History

The first horse-powered streetcar line in the city of Karlsruhe was opened in 1877. Increasing population and the growth of the city made it necessary to improve transportation within the city. In addition to the first east-west connection through the city center that today is still the main streetcar line in Karlsruhe, another branch to the city's main station was opened shortly thereafter. In 1894, the AEG began an electrification of the growing network that kept expanding in the following decades.

Although the streetcar system was partially destroyed in World War II the operation resumed in 1945 and repairs were completed by 1950. Like most other German cities the post war era brought rapid motorization and suburbanization in Karlsruhe. Instead of following the zeitgeist in Germany in the post war era, the city of Karlsruhe decided not to replace streetcar operation with busses, but to keep relying on streetcar operation. Improvements in operations occurred by placing the streetcar tracks next to the street instead of in the street. Unlike many other German cities the streetcar network kept expanding during the 1970s and 80s. In the following era of the Karlsruher Modell and the Stadtbahn, only minor system expansions took place since the main emphasis by officials was put on expansion of the new Regio-Stadtbahn network. [70]

Network

While the Stadtbahn network of the AVG reaches from the city center far into the region, the streetcar network operated by the VBK is limited to the city of Karlsruhe. With a very dense system of eight streetcar lines the majority of the population lives within walking distance of a streetcar stop. All lines except lines 2E and 8 serve the central "Marktplatz" station and pass through the city center serving various outlying neighborhoods (see Figure12). Line 2E bypasses the central part of the network in the south and terminates at the main railroad station. The short line 8 only connects two outlying neighborhoods without ever going into the central part of the city of Karlsruhe. [68]

3.5.3 Karlsruhe Bus

Network

Because of the extensive rail network in the city of Karlsruhe the bus network is extremely limited (see Figure 14), with 24 bus lines serving mainly the few areas of the city that do not have good access to the rail network. While the bus network itself is not very well interconnected (several local sub-networks have emerged), all bus lines do connect to the rail network. [71]

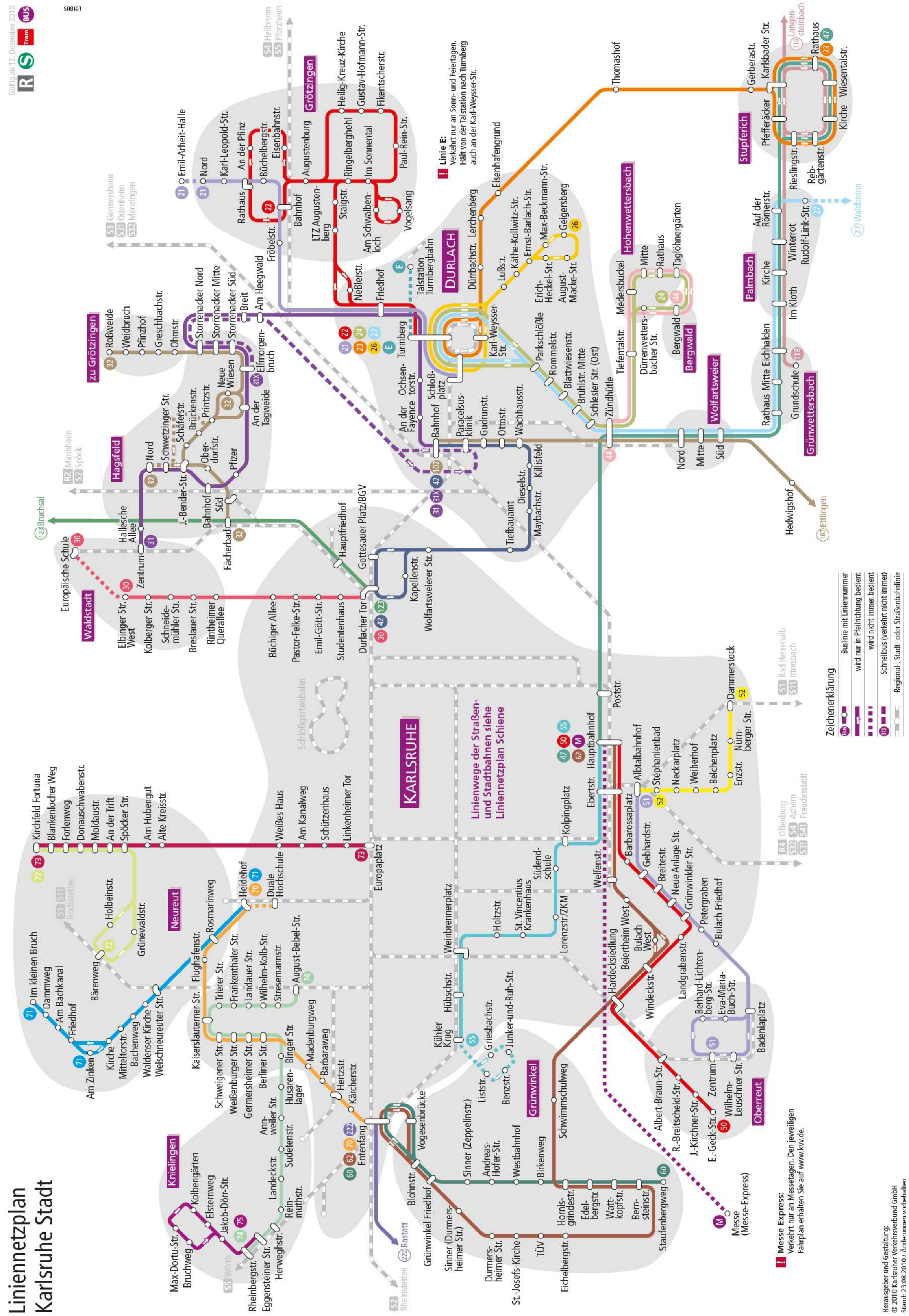

Figure 13 - Bus Network in the City of Karlsruhe [71]

3.6 Atlanta

The city of Atlanta is the capital of the state of Georgia in the southeastern United States. Today the city has a population of about 420,000 people [72] although this number increases greatly if the suburbs in the surrounding counties are included. For this research the counties of Fulton, DeKalb, Cobb, Gwinnett and Clayton have been included because they lie at the heart of the Atlanta metropolitan region. Transit services in Fulton and DeKalb Counties are offered by the Metropolitan Atlanta Rapid Transit Authority (MARTA). Centered on the city of Atlanta, MARTA runs a heavy rail subway system and an additional local bus system that spans both counties.

Neither Cobb nor Gwinnett County participate in MARTA and instead run their own transit systems. Cobb Community Transit (CCT) and Gwinnett County Transit (GCT) operate bus networks in their respective counties. Although CCT and GCT are not a part of MARTA they use the same fare collection system, the Breeze Card/Ticket, and CCT, GCT and MARTA offer free transfers among the systems. A transit service in Clayton County (CTRAN) was terminated in March, 2010.

A regional transit service of express bus routes through the whole region is offered by the State of Georgia through its Georgia Regional Transportation Authority (GRTA). The GRTA buses operate under the brand “Xpress”.

3.6.1 MARTA

<u>History</u>

The city of Atlanta used to have an extensive streetcar network spanning the entire city. The streetcars emerged in the years following the American Civil War in which the city (an important railroad hub) had been largely destroyed. The streetcar system grew with the rise of the new city in the late nineteenth century, but eventually was discontinued in the mid 20th century because of the increasing popularity of the automobile and the bus. [73]

In 1972, the newly created Metropolitan Atlanta Rapid Transit Authority (MARTA) took over the existing transit system in Atlanta and started developing a new rail system for the region. The voters in Fulton and DeKalb Counties and in the city of Atlanta had passed a referendum implementing a one percent sales tax in order to finance MARTA's transit operation. The referendum was not approved by the electorate in Cobb, Gwinnett and Clayton Counties, and thus they were excluded from MARTA's service area. After 1972, construction on MARTA's new rail system was underway and in 1979 the first train rolled between Avondale and Georgia State University on the east-west line. Major construction on the system continued through the 1980s. Service extension continued at a slower pace in the 90s and 2000s. [16]

Network

The MARTA system is dominated by two rail routes (see Figure 14). Two lines run east-west and the north-south. The north-south route is being served by the Red and Gold lines that split into two directions just north of Lindbergh Center station. Together they serve the north of the city of Atlanta including Atlanta's second downtown, Buckhead, and the northern part of Fulton and DeKalb Counties. In the south, both lines terminate at Hartsfield-Jackson Atlanta International Airport, which is technically a part of Clayton County. The east-west route is home to the Green and Blue lines. While the Green line has its eastern terminus at Edgewood station, the Blue line continues and serves the city of Decatur and finally terminates at Indian Creek station outside the

Atlanta Beltway (I-285). On the western line, the Blue and the Green lines split into two different branches west of Ashby station. All four lines meet at the central hub of the system, the Five Points station in downtown Atlanta.

Besides the subway system, MARTA also operates a bus system in Fulton and DeKalb Counties that was designated to serve as feeders to the rail network and also establish connections to the neighboring counties and into areas that are not served by rail (see Figure 15). [74]

Figure 14 - MARTA's Rail Network [74]

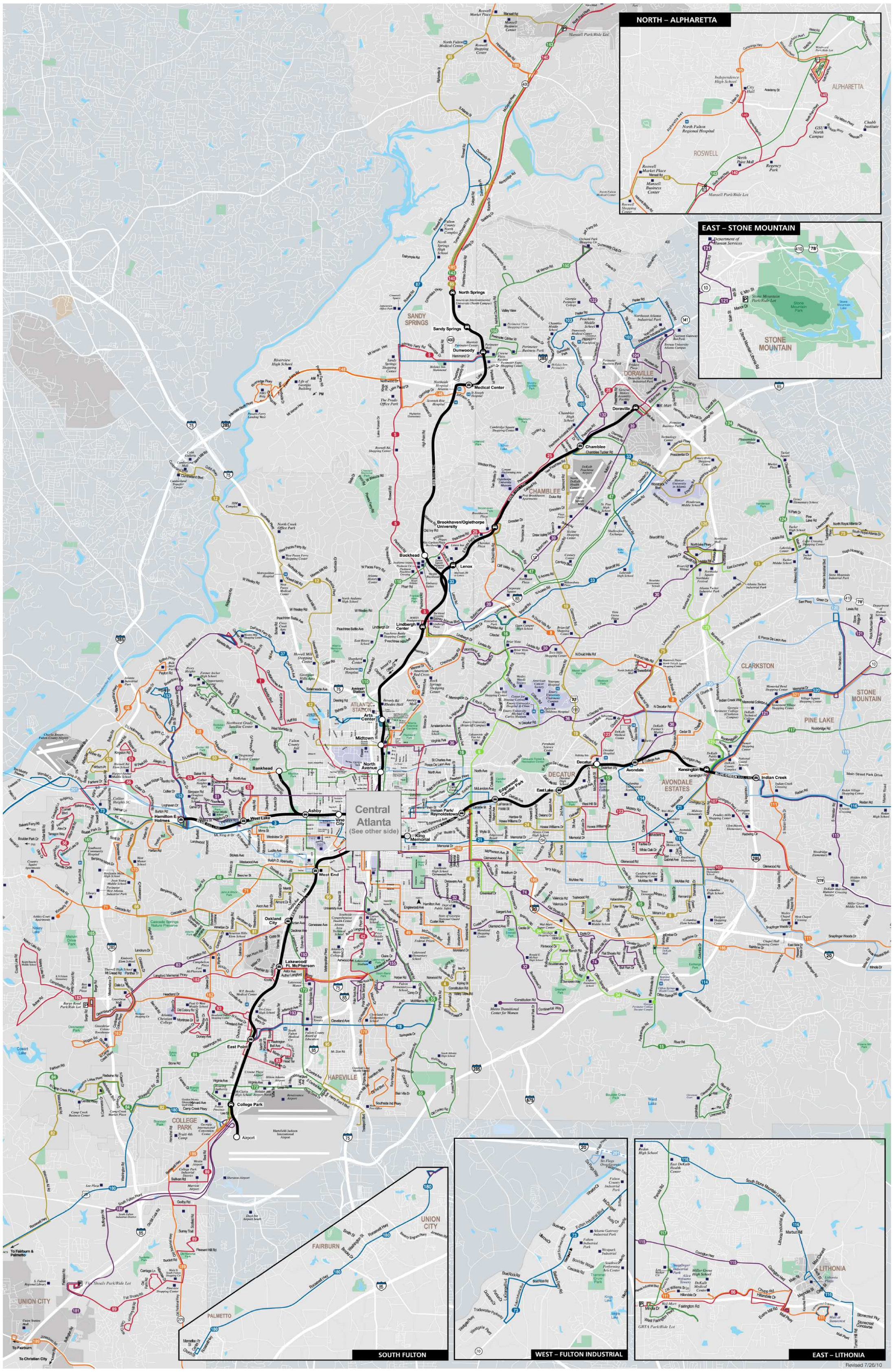

Figure 15 - The MARTA System Including Bus Routes [74]

3.6.2 Cobb Community Transit

Network

Cobb Community Transit (CCT) operates a system of local bus routes that run mainly parallel to I-75 and into southern Cobb County (see Figure 16). Three local bus routes (number 10, 30 and 35) run into Fulton County with the first one connecting to the MARTA Arts Center station and the others connecting to the Hamilton E. Holmes station. In addition to the local bus service, CCT also offers three express bus routes from Acworth, Kennesaw and Marietta to Midtown Atlanta that run on I-75 for almost their entire journey.

3.6.3 Gwinnett County Transit

Network

Similar to CCT, Gwinnett County Transit (GCT) only operates a basic network of bus routes connecting the activity and population centers in southeastern and central Gwinnett County. Local bus route 10 enters Fulton County and connects to the Doraville MARTA station (see Figure 17). In addition to the local routes, GCT offers three express routes that start at park-and-ride lots (Indian Trail, Discover Mills, and I-985) along the major interstate corridor and connect to the Five Points MARTA station in downtown Atlanta. [76]

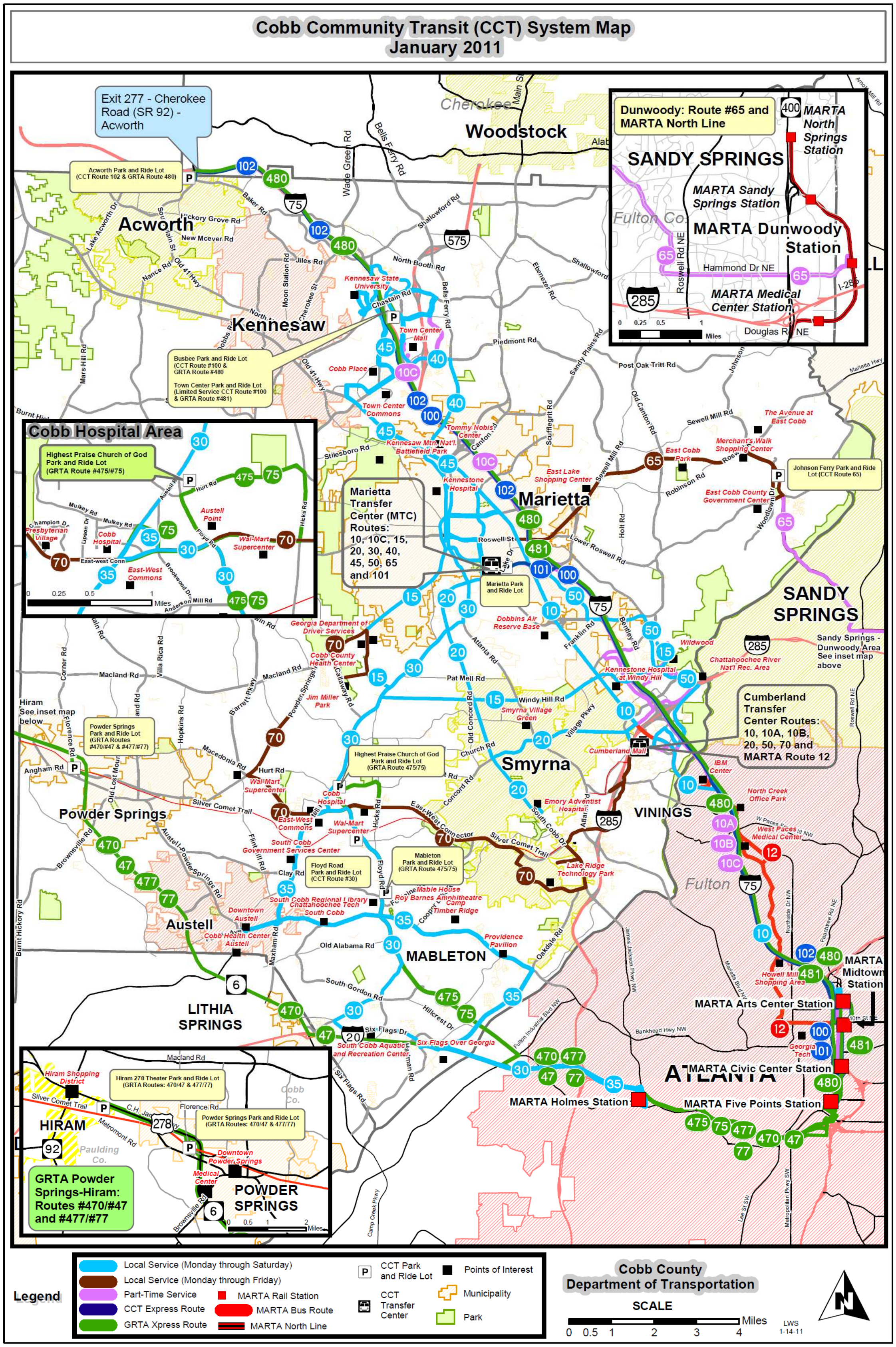

Figure 16 - Bus Lines Serving Cobb County [75]

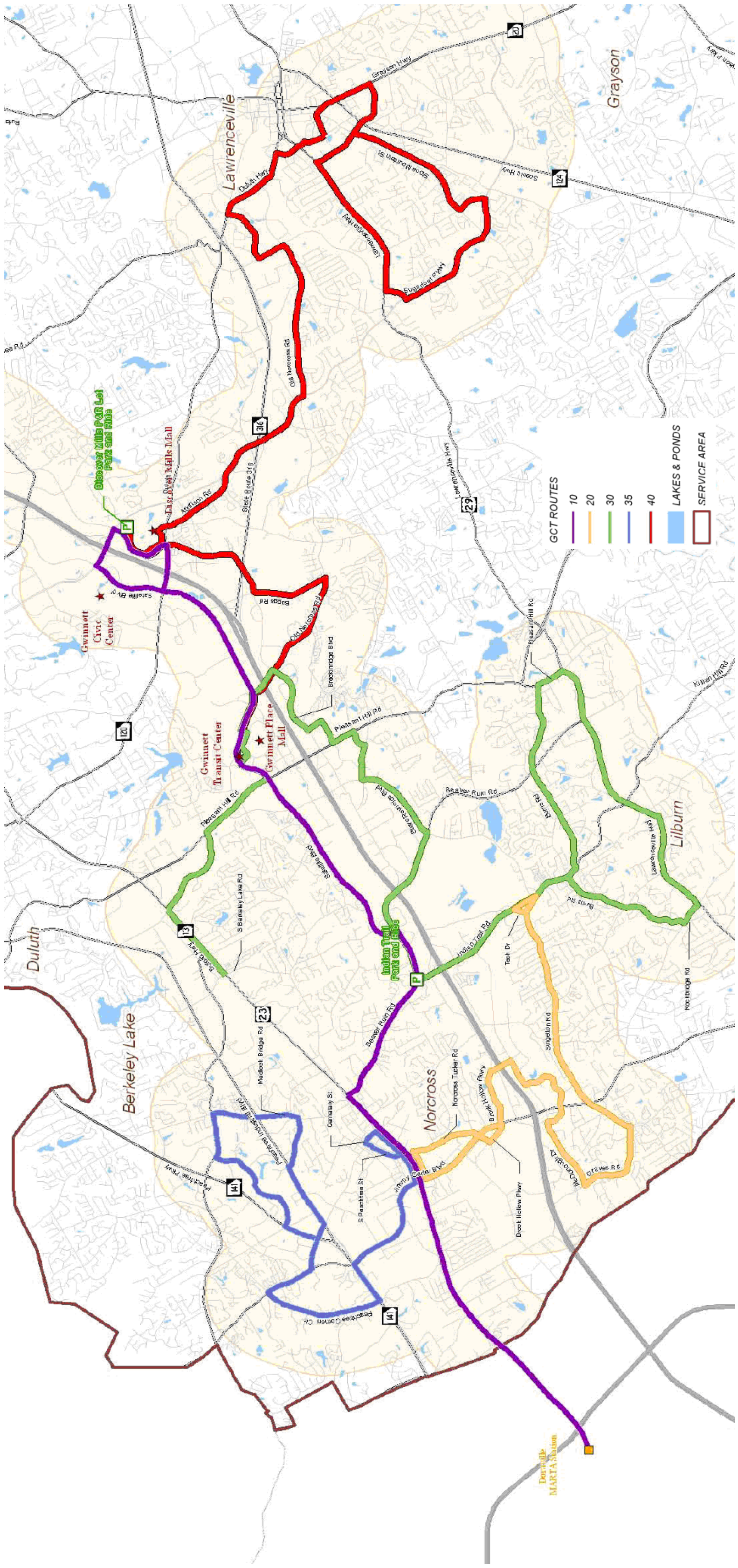

Figure 17 - Gwinnett County Transit Network [76]

3.7 Data Tables

The following tables provide an overview of the data that was collected for the comparison of the systems and agencies.

Table 2 - Collected System Data

City	System	# of lines [-]	length: total track [mi]	length: total line [mi]	length: average line [mi]	# of stations [-]	avg. station spacing [mi]
Atlanta	MARTA Rail	4 [74]	47.4 [77]	67.7 [77]	16.93	38 [74]	1.394
	MARTA Bus	91 [74]		1,062.1 [77]	10.99	5129 [77]	N/A
	CCT BUS	21 [78]		202.8	9.66	630 [79]	0.333 [79]
	GCT BUS	12 [80]		207.7 [80]	17.31	250 [80]	N/A
Berlin	S-Bahn	15 [22]	205.1 [81]	363.3 [81]	24.22	166 [82]	1.340
	U-Bahn	10 [83]	90.3 [81]	90.9 [83]	9.09	173 [83]	0.491 [83]
	Streetcar	22 [83]	117.4 [81]	184.4 [83]	8.38	374 [83]	0.311 [83]
	Bus	149 [83]		1,040.8 [83]	6.99	2619 [83]	0.298 [83]
Hamburg	S-Bahn	6 [84]	91.3 [84]	160.9 [84]	26.82	68 [84]	1.059 [84]
	U-Bahn	3 [85]	62.6 [86]	62.6 [85]	20.86	89 [85]	0.646 [86]
	Bus	114 [85]		575.0 [85]	5.04	1325 [85]	0.311 [86]
Munich	S-Bahn	10 [87]	274.6 [87]	329.3 [87]	32.93	148 [87]	1.990
	U-Bahn	6 [88]	57.8 [88]	57.8 [88]	9.63	94 [88]	0.616 [88]
	Streetcar	11 [88]	46.6 [88]	46.6 [88]	4.24	155 [88]	0.298 [88]
	Bus	66 [88]		284.0 [88]	4.30	915 [88]	0.310 [88]
Hanover	S-Bahn	7 [89]	239.2 [90]	313.2 [90]	44.74	74 [90]	3.233 [90]
	LRT	12 [91]	88.2 [91]	96.2	8.02 [57]	195 [91]	0.379 [92]
	Bus	40 [93]		270.9	6.77 [57]	684 [93]	0.350 [92]
Karlsruhe	S-Bahn	10 [69]	176.8 [94]	285.9 [94]	28.59	354 [68]	0.514
	Streetcar	8 [68]	42.8 [95]	76.6 [95]	9.57	135 [96]	0.317 [96]
	Bus	24 [68]		92.5 [95]	3.85	244 [68]	0.281

Table 2 continued - Collected System Data

City	System	annual ridership [x1000]	person-mi/year [mi]	train-mi/year [mi]	frequency of service: rush hour [min]	frequency of service: non-rush hour [min]	weekday hours of operation
Atlanta	MARTA Rail	83,346 [10]	527,022,801 [10]	4,500,147 [10]	15 [97]	20 [97]	4am-2am [97]
	MARTA Bus	72,716 [10]	285,048,156 [10]	30,991,759 [10]	15-30 [97]	30-60 [97]	4am-2am [97]
	CCT BUS	4,553 [10]	40,411,398 [10]	3,968,625 [10]	15-30 [98]	30-60 [98]	6am-9pm [98]
	GCT BUS	2,100 [80]	35,197,055 [80]	3,055,990 [80]	15-30 [99]	30-60 [99]	5am-9pm [99]
Berlin	S-Bahn	371,000 [82]	2,263,039,507 [82]	17,460,574 [82]	10 [100]	20 [100]	4am-3am [100]
	U-Bahn	495,900 [83]	1,551,070,625 [101]	12,489,592 [101]	5 [100]	10-15 [100]	4am-3am [100]
	Streetcar	166,500 [83]	341,195,770 [101]	11,806,082 [101]	10 [100]	20 [100]	24h [100]
	Bus	386,700 [83]	795,543,515 [101]	54,556,526 [101]	10 [100]	15-20 [100]	24h [100]
Hamburg	S-Bahn	221,000 [102]	1,172,530,354 [102]	7,829,296 [102]	10 [84]	20 [84]	4am-12:30am [84]
	U-Bahn	194,858 [85]	711,695,478 [85]	7,183,744 [85]	5 [103]	10 [103]	4am-1am [103]
	Bus	206,768 [85]	399,707,955 [85]	28,448,308 [85]	5-10 [103]	10-20 [103]	4:30am-12am [103]
Munich	S-Bahn	268,000 [104]	2,299,079,126 [104]	12,606,410 [41]	10 [45]	20 [45]	24h [45]
	U-Bahn	351,000 [88]	N/A	6,546,783 [41]	5 [105]	10-20 [105]	4am-2:30am [105]
	Streetcar	94,500 [88]	N/A	4,291,821 [41]	5-10 [105]	20 [105]	4:30am-1:30am [105]
	Bus	172,000 [88]	N/A	17,197,733 [41]	5-10 [105]	20 [105]	4:30am-2am [105]
Hanover	S-Bahn	29,224 [90]	413,950,439 [90]	5,281,668 [89]	30-60 [57]	30-60 [57]	4am-12:30am [90]
	LRT	125,000 [91]	379,596,605 [92]	15,301,304 [92]	10 [92]	15-30 [92]	4am-1am [92]
	Bus	30,000 [106]	71,954,963 [92]	8,589,857 [92]	20 [92]	30 [92]	4am-2am [92]
Karlsruhe	S-Bahn	70,000 [94]	N/A	10,936,160 [94]	10 [107]	20 [107]	24h [107]
	Streetcar	97,300 [95]	N/A	5,654,492 [95]	10 [107]	20 [107]	24h [107]
	Bus	13,900 [95]	N/A	2,547,628 [95]	20 [107]	30 [107]	5am-1am [107]

Table 2 continued - Collected System Data

City	System	total operating cost [$]	ticket revenue [$]	fare structure	ticket prices [$]
Atlanta	MARTA Rail	373,208,870 [10]	103,984,311 [10]	flat [108]	2 [108]
	MARTA Bus			flat [108]	2 [108]
	CCT BUS	17,487,984 [10]	4,954,670 [10]	flat [109]	2 (expr. 4) [109]
	GCT BUS	11,411,772 [10]	4,273,216 [10]	flat [110]	2 (expr. 3) [110]
Berlin	S-Bahn	N/A	N/A	zones [111]	1.96-4.2 [111]
	U-Bahn	1,293,460,000 [101]	710,360,000 [101]	zones [111]	1.92-3.22 [111]
	Streetcar			zones [111]	1.92-3.22 [111]
	Bus			zones [111]	1.92-3.22 [111]
Hamburg	S-Bahn	N/A	N/A	zones [112]	3.92-10.71 [112]
	U-Bahn	672,169,400 [85]	453,490,800 [85]	zones [112]	1.82-3.92 [112]
	Bus			zones [112]	1.82-3.92 [112]
Munich	S-Bahn	N/A	N/A	zones [113]	3.5-14 [113]
	U-Bahn	510,020,000 [114]	N/A	zones [115]	1.68-7.0 [115]
	Streetcar			flat within zone [115]	1.68-3.5 [115]
	Bus			flat within zone [115]	1.68-3.5 [115]
Hanover	S-Bahn	N/A	N/A	zones/distance [116]	3.22-24.36 [116]
	LRT	313,128,058 [117]	178,827,600 [117]	zones [118]	1.96-4.2 [118]
	Bus			zones [118]	1.96-4.2 [118]
Karlsruhe	S-Bahn	N/A	N/A	zones [119]	2.38-7.7 [119]
	Streetcar	183,859,219 [95]	129,582,332 [95]	flat within zone [119]	2.38-3.08 [119]
	Bus			flat within zone [119]	2.38-3.08 [119]

Table 3 - Demographic and Geographic City Information

		population [-]	area [mi²]	pop. density [1/mi²]
Atlanta	City	420,000 [120]	131 [120]	3,206
	Region	3,579,661 [120]	1,712 [120]	2,090
Berlin	City	3,443,675 [18]	344 [18]	9,999
	Region	N/A	N/A	N/A
Hamburg	City	1,772,000 [30]	292 [30]	6,079
	Region	3,370,000 [121]	3,327 [121]	1,013
Munich	City	1,317,000 [41]	120 [41]	11,003
	Region	2,669,000 [41]	2,124 [41]	1,257
Hanover	City	519,212 [50]	79 [50]	6,592
	Region	1,130,000 [122]	1,424 [122]	794
Karlsruhe	City	283,048 [64]	67 [64]	4,226
	Region	1,331,000 [123]	1,371 [123]	971

CHAPTER 4

INTERPRETATION

4.1 City Comparison

With just over 3200 people per square mile, the city of Atlanta has the lowest population density of all cities in the research, while the city of Munich has the highest with just over 11,000, almost 3.5 times as high. (Table 4) The encompassing Atlanta region on the other hand has the highest population density of all the regions surrounding the six case study cities. This suggests that the five German regions are still centered on the respective city center. Although the Atlanta region has the highest population of all regions, the high sprawl in Atlanta could make it difficult, especially for rail transit, to work effectively because service would have to be spread over a much wider area.

This challenge is reflected in the annual ridership (trips) per capita. The Atlanta region has the lowest number of trips per capita (45) (Table 4) while the Munich region has the highest number of trips on a regional basis (332). The number of trips per capita on the other hand appears to be quite high at the city level. With 387 trips per capita, Atlanta has just slightly less than Berlin and more than Hamburg and Hanover.

The same tendency can be noted when comparing the passenger miles per capita. While the Atlanta region has the lowest level in the sample, the city of Atlanta has the most transit miles traveled per capita. (Table 4)

It should be kept in mind that the transit system in the Atlanta region - although centered on the city of Atlanta - operates mainly outside of the city itself. This is different in the five German cities (especially in Berlin and Hamburg) where almost all transit service included in this research takes place within the city while most of the regional service has been left out of the research. Thus, Atlanta's comparatively high ridership per capita results from the high ratio between the population size of the region and the city.

Table 4 - Population, Density and Transit Use in each City

		pop. [-]	area [mi²]	density [1/mi²]	ridership/pop [-]	p.miles/pop [mi]
Atlanta	City	420,000	131	3,206	387	2,114
	Region	3,579,661	1,712	2,090	45	248
Berlin	City	3,443,675	344	9,999	412	1,438
	Region	N/A	N/A	N/A	N/A	N/A
Hamburg	City	1,772,000	292	6,079	351	1,289
	Region	3,370,000	3,327	1,013	185	678
Munich	City	1,317,000	120	11,003	672	N/A
	Region	2,669,000	2,124	1,257	332	N/A
Hanover	City	519,212	79	6,592	355	1,667
	Region	1,130,000	1,424	794	163	766
Karlsruhe	City	283,048	67	4,226	640	N/A
	Region	1,331,000	1,371	971	136	N/A

4.2 Network Characteristics

4.2.1 Rail Networks

<u>Line Characteristics</u>

When comparing the number of rail lines operating in each system it turns out that MARTA's four rail lines make it the rail system with the second least number of lines in the dataset. (Table 5) Only the U-Bahn Hamburg has one line less than MARTA. The system with the most lines is the Streetcar Berlin with 22 lines. Regarding total line length all streetcar/light-rail systems and also the U-Bahn in Berlin and Munich have considerably shorter average line lengths than the MARTA rail system. Of the subway systems only the U-Bahn Hamburg has a longer average rail line length than MARTA.

However, the S-Bahn systems in all of the five German regions have longer average line lengths than MARTA. This places MARTA somewhere in the middle between Streetcar/U-Bahn on the one side and the S-Bahn systems on the other.

Network Size

In comparison to the German rail networks the MARTA rail system finds itself among the smallest of all. (Table 5) Only the streetcar systems in Munich and Karlsruhe have a shorter network of track mileage than the 47.4 mile MARTA rail network. The S-Bahn systems in all five German regions especially have longer networks than MARTA. This of course makes sense because of the regional focus these systems have as opposed to the urban focus of the subway systems.

In terms of total line length, the MARTA rail system is somewhat similar to the U-Bahn systems in Hamburg and Munich. Again the S-Bahn systems naturally have the longest total line length while the streetcar system in Munich has the shortest. When comparing total track length and total line length it is striking that the lines of all German U-Bahn systems have their own track and do not share it with other lines. This can be inferred from the fact that the total track length and the total line length are identical. The MARTA system, however, has a lot of shared tracks (the north-south main line and the east-west main line) on each of which two lines are operating. So again the MARTA rail system can not clearly be identified as similar to a typical German U-Bahn system.

Stations

When comparing the total number of rail stations it can be seen that the MARTA rail system has the smallest number of stations in the system. (Table 5) Generally the streetcar systems have the most number of stations in each city with the exception of the extensive S-Bahn system in Karlsruhe. This also results in a relatively short average station spacing of the streetcar systems which varies around 0.3 miles. The U-Bahn systems on the other hand have an average station spacing of around 0.5 (Berlin) to 0.65 (Hamburg) miles while the 1.394 miles average station spacing in Atlanta is much longer than that. Regarding the station spacing the MARTA rail system resembles much more the characteristics of the German S-Bahn systems. The S-Bahn systems have an average station spacing of around 1.0 to 2.0 miles (with the exception of the "special" two system Karlsruhe S-Bahn). (Table 5)

All in all it can be said that the MARTA rail system does not resemble the German U-Bahn systems. Some characteristics such as the short track and line length are similar to the characteristics of the U-Bahn systems. However, in general, the MARTA rail system seems much more similar to the S-Bahn systems with shared track operation and larger station spacing.

Table 5 - Rail Network Characteristics

Rail Systems			length			stations	
City	**System**	# of lines [-]	avg. line [mi]	total track [mi]	total line [mi]	total # [-]	avg. spacing [mi]
Atlanta	MARTA	4	16.93	47.4	67.7	38	1.394
Berlin	S-Bahn	15	24.22	205.1	363.3	166	1.340
	U-Bahn	10	9.09	90.3	90.9	173	0.491
	Streetcar	22	8.38	117.4	184.4	374	0.311
Hamburg	S-Bahn	6	26.82	91.3	160.9	68	1.059
	U-Bahn	3	20.86	62.6	62.6	89	0.646
Munich	S-Bahn	10	32.93	274.6	329.3	148	1.990
	U-Bahn	6	9.63	57.8	57.8	94	0.616
	Streetcar	11	4.24	46.6	46.6	155	0.298
Hanover	S-Bahn	7	44.74	239.2	313.2	74	3.233
	LRT	12	8.02	88.2	96.2	195	0.379
Karlsruhe	S-Bahn	10	28.59	176.8	285.9	354	0.514
	Streetcar	8	9.57	42.8	76.6	135	0.317

4.2.2 Bus Networks

Line Characteristics

Looking at the number of operating bus lines it is obvious that the Atlanta bus system is one of the major bus systems in the dataset. Only the 149 bus lines in Berlin can surpass the 124 bus lines in the Atlanta region. (Table 6) The bus systems in Karlsruhe and Hanover have the least number of bus lines, which might be due to the relatively small population and the strong rail dominance in both their transit systems.

When it comes to the average bus line length, Atlanta has the highest value of all systems in this research. (Table 6) This shows that compared to the German cities the bus system in the Atlanta region is much more important in terms of service coverage. The difference in the average bus line lengths also corresponds very well with the number of bus lines per one million inhabitants. The city with the shortest average bus line length, Karlsruhe, also has the most bus lines in relation to the population size. This also makes clear that the number of bus lines itself is of limited meaningfulness for a comparison and should always only be used in connection to the total line length.

Network Size

The importance of the bus system for the Atlanta transit system becomes even clearer when regarding the total line length. The 1472.6 miles of total bus line length in the Atlanta region exceeds the length in each German city. (Table 6) Instead of maintaining an extensive rail system to provide transit in the sprawling Atlanta region the local transit agencies are focusing much more on bus service than their German counterparts. The extent of the Atlanta bus system gets even clearer when comparing the total line length per one million inhabitants. In relation to population size only the

Hanover bus system offers more network miles. (Table 6) This supports the conclusion that because of the low population density in the Atlanta region the Atlanta bus network has to be much larger than in the German cities to offer adequate service to a comparable number of people.

Stations and Stops

The Atlanta bus network has by far the most number of stations or stops. With 6009 bus stops it has more than twice as many as the largest German system in Berlin. (Table 6) The average bus stop spacing on the other hand is more or less similar in all systems for which data was available. It ranges around 0.3 miles for all systems and is therefore similar to the streetcar station spacing. (Table 6)

Table 6 - Bus Network Characteristics

Bus Systems		# of lines		line length			stations	
City	**System**	total [-]	per 1 mil. inhab. [-]	avg. [mi]	total [mi]	per 1 mil. inhab. [mi]	total number [-]	average spacing [mi]
Atlanta	MARTA	124	35	11.88	1,472.6	411	6009	N/A
	CCT							0.333
	GCT							N/A
Berlin	Bus	149	43	6.99	1,040.8	302	2619	0.298
Hamburg	Bus	114	64	5.04	575.0	324	1325	0.311
Munich	Bus	66	50	4.30	284.0	216	915	0.310
Hanover	Bus	40	77	6.77	270.9	522	684	0.350
Karlsruhe	Bus	24	85	3.85	92.5	327	244	0.281

4.3 Operational Characteristics

4.3.1 Rail

Ridership

The dominant rail system in this comparison with regard to total ridership is the U-Bahn Berlin with almost 500 million riders every year. Other systems such as the S-Bahn Berlin and the U-Bahn Munich also have a very high ridership. Compared to these high-ridership systems the MARTA rail system has a relatively low ridership. (Table 7) This becomes even more obvious when plotting the total ridership over the total line length of the systems. (Figures 18, 19 and 20) When compared to the other subway systems the plot (Figure 18) shows that even though the line length of the MARTA rail system is more than that of the U-Bahn's in Munich and Hamburg it fails to attract an equal number of riders. Even when compared to streetcar systems the MARTA rail system still has a slightly lower ridership than systems with comparable total line length (Karlsruhe and Munich). (Figure 20) Only in comparison with the German S-Bahn systems does the performance of the MARTA rail system somewhat compete with the German systems. (Figure 18) The S-Bahn systems in Hanover and Karlsruhe even attract fewer riders than the MARTA system although their total line lengths are much longer. Again the characteristics of the MARTA rail system seem to resemble more those of a German S-Bahn system than a German U-Bahn system.

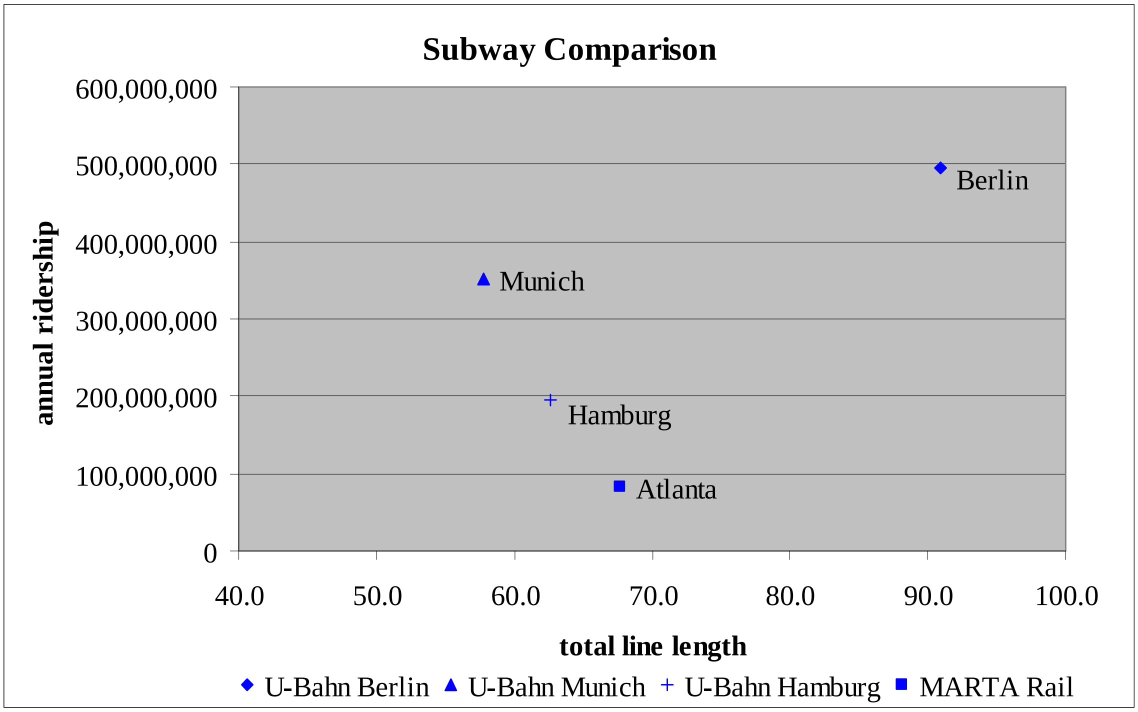

Figure 18 - Subway Comparison: Ridership and Network Length

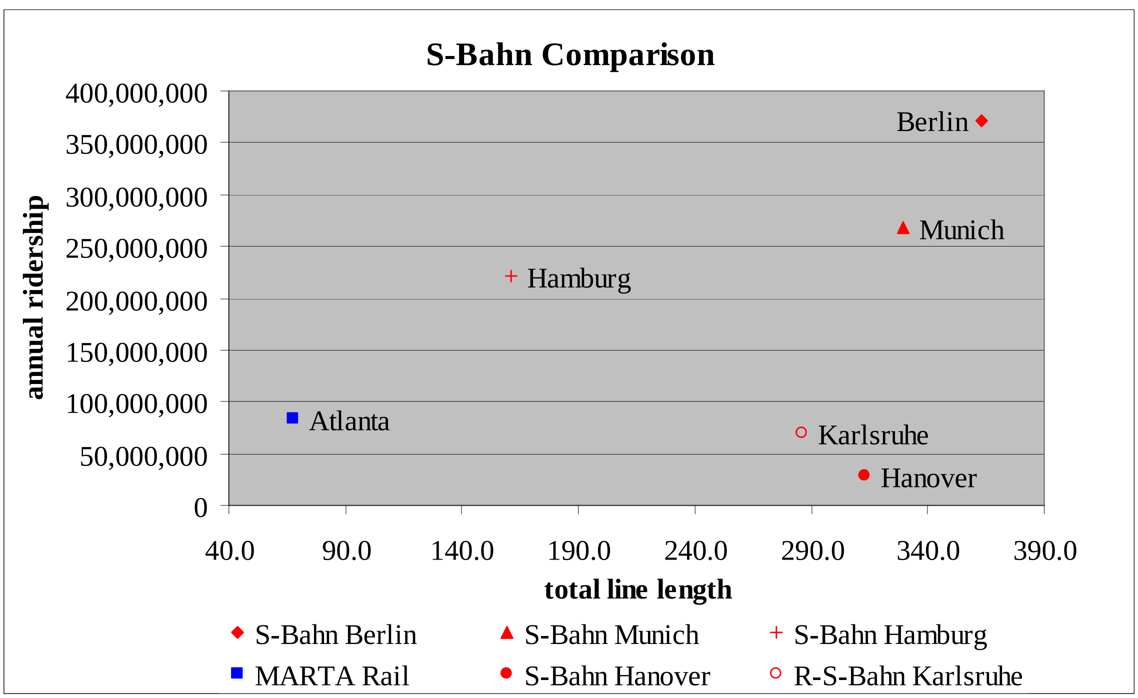

Figure 19 - S-Bahn Comparison: Ridership and Network Length

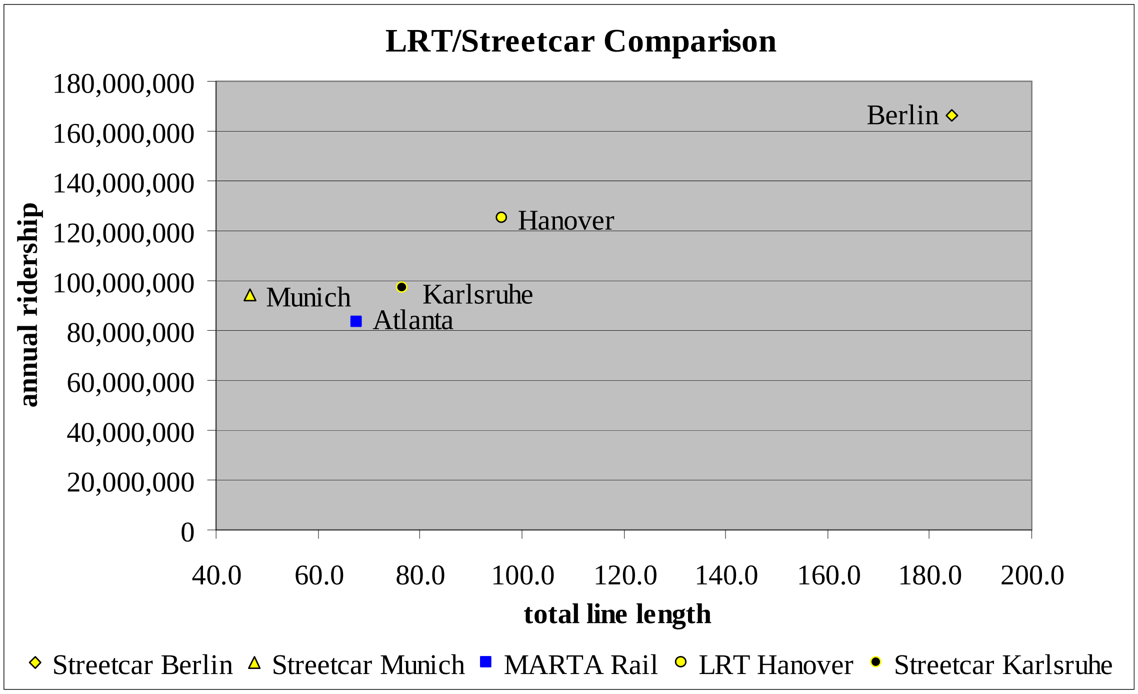

Figure 20 - LRT/Streetcar Comparison: Ridership and Network Length

<u>Transportation Performance</u>

On a passenger mile per rider basis the MARTA rail system has fairly similar values to the German S-Bahn systems. (Table 7) Each rider on the MARTA system rides about 6.3 miles, which is in the same range as the distance traveled by an average rider in the S-Bahn's in Berlin, Hamburg and Munich and much more than the average traveling distance in the U-Bahn and streetcar/LRT systems. This feature is of course supported by the similarity in the station spacing and the regional coverage of the MARTA rail system and the S-Bahn systems. (See: Network Characteristics)

With respect to the average occupancy of the trains the MARTA system ranks in fifth place behind the S-Bahn's in Munich, Hamburg and Berlin and the U-Bahn Berlin. (Table 7) However, this estimate is of limited value since it does not take the size and capacity of the trains into account.

Offered Service

Of all rail systems investigated in this research, the S-Bahn Hanover has the longest service headways. The MARTA rail system is second to last with a typical rush hour headway of 15 minutes on each line, which is much more than the 5 minutes typical for the German U-Bahn systems. (Table 7) The MARTA system's characteristics resemble more those of the German S-Bahn systems, which (except for the S-Bahn Hanover) all have rush hour headways of 10 minutes. During the non-peak hours the average headways of all rail systems are fairly similar with around 15-20 minutes (except S-Bahn Hanover). However, this headway measurement does not take into account that there are always two lines running on the same main line in the MARTA system, which reduces the effective headway depending on the destination of the rider. This is also the case for the S-Bahn systems, which (e.g. the S-Bahn Munich) have even more rail lines running on the same main line and therefore have an even shorter effective headway.

The weekday hours of operation of all rail systems are very extensive with the streetcars in Berlin and Karlsruhe and the S-Bahn's in Karlsruhe and Munich operating 24 hours a day. (Table 7) The other systems all start operation around 4am and have a short operations break during the night starting between 12:30am (S-Bahn Hamburg and Hanover) and 3am (S- and U-Bahn Berlin).

Table 7 - Operational Characteristics: Rail Systems

Rail Systems City	System	ridership annual [x1000]	passenger-miles per rider [mi]	passenger-miles per train mi. [mi/mi]	frequency of service rush hour [min]	frequency of service non-rush hour [min]	weekday hours of operation
Atlanta	MARTA	83,346	6.32	117.1	15	20	4am-2am
Berlin	S-Bahn	371,000	6.10	129.6	10	20	4am-3am
	U-Bahn	495,900	3.13	124.2	5	10-15	4am-3am
	Streetcar	166,500	2.05	28.9	10	20	24h
Hamburg	S-Bahn	221,000	5.31	149.8	10	20	4am-12:30am
	U-Bahn	194,858	3.65	99.1	5	10	4am-1am
Munich	S-Bahn	268,000	8.58	182.4	10	20	24h
	U-Bahn	351,000	N/A	N/A	5	10-20	4am-2:30am
	Streetcar	94,500	N/A	N/A	5-10	20	4:30am-1:30am
Hanover	S-Bahn	29,224	14.16	78.4	30-60	30-60	4am-12:30am
	LRT	125,000	3.04	24.8	10	15-30	4am-1am
Karlsruhe	S-Bahn	70,000	N/A	N/A	10	20	24h
	Streetcar	97,300	N/A	N/A	10	20	24h

4.3.2 Bus

Ridership

The annual ridership of the Atlanta bus system is much less than that of the big German cities Berlin, Hamburg and Munich. Only the rail-dominated and much smaller cities of Hanover and Karlsruhe have a lower ridership on their bus systems than the Atlanta region. (Table 8) When put in relation to the total line length of the bus system it can clearly be seen that although the Atlanta region has the most extensive bus system it does not attract as many riders as the smaller systems in Munich, Hamburg and Berlin. (Figure 21)

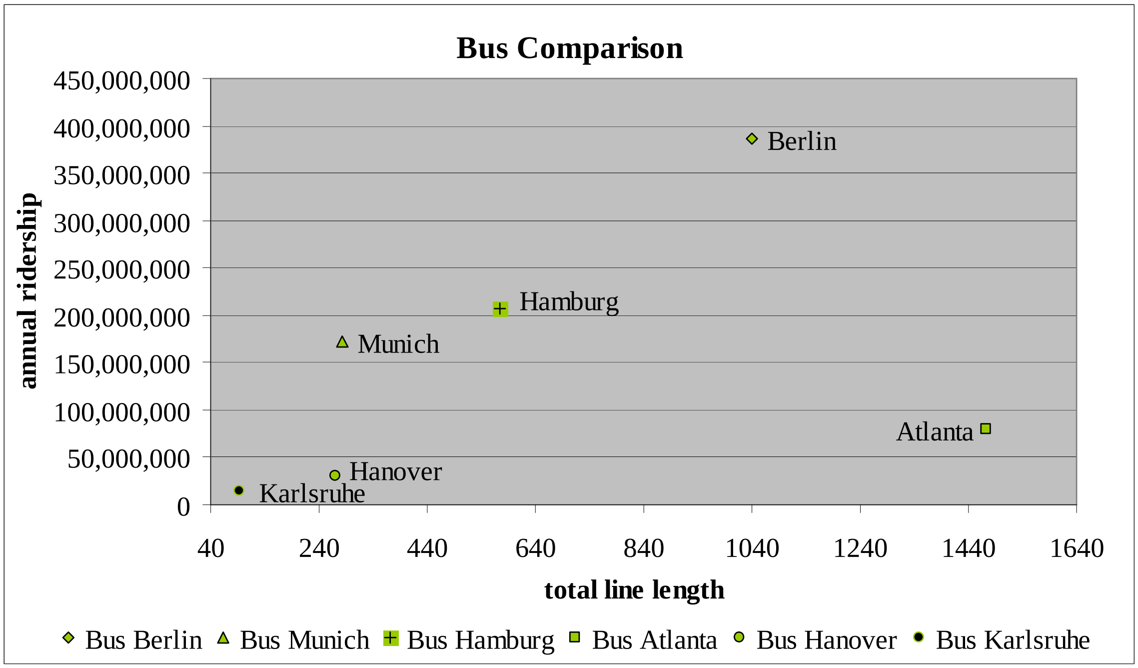

Figure 21 - Bus Comparison: Ridership and Network Length

Transportation Performance

Comparing the average distance traveled by the passengers in the different bus systems, the passengers in Atlanta travel distances more than twice as long as the passengers in the German bus systems for which data was available. (Table 8) The average occupancy of the busses in Atlanta is lower than in Berlin and Hamburg, but higher than in the Hanover bus system. This suggests that although having about the same population as Berlin (see: City Comparison) the Atlanta region does not have comparable bus occupancy, which is caused by the low population density and the challenges for effective bus operation that come with it. Other factors such as convenience of the transit systems and different cultural habits might also be a cause for the low ridership.

Offered Service

The bus service frequency in the Atlanta region varies widely depending on the bus line that is taken. The rush hour headways of 15 minutes on the major bus routes are somewhat similar to the rush hour headways on the German systems. (Table 8) The only German cities with typical rush hour headways of more than 10 minutes are Hanover and Karlsruhe with their strong dominance of rail service. During non-rush hours the Atlanta bus system has the least appealing headways on their bus lines. (Table 8) Headways of 30 to 60 minutes can only compete with the typical non-rush hour headways in Hanover and Karlsruhe. This focus on the peak hours especially on the suburban bus routes of the Atlanta region can also be seen in the hours of operation. The bus systems of CCT and GCT only operate until 9pm on weekdays while all other systems (including MARTA) offer weekday service at least until 12am with the Berlin system even running a 24h service.

Table 8 - Operational Characteristics: Bus Systems

Bus Systems		ridership	passenger miles		frequency of service		
City	**System**	annual [x1000]	per rider [mi]	per bus mi. [mi/mi]	rush hour [min]	non-rush hour [min]	weekday hours of operation
Atlanta	MARTA CCT GCT	79,370	4.54	9.5	15-30	30-60	4am-2am 6am-9pm 5am-9pm
Berlin	Bus	386,700	2.06	14.6	10	15-20	24h
Hamburg	Bus	206,768	1.93	14.1	5-10	10-20	4:30am-12am
Munich	Bus	172,000	N/A	N/A	5-10	20	4:30am-2am
Hanover	Bus	30,000	2.40	8.4	20	30	4am-2am
Karlsruhe	Bus	13,900	N/A	N/A	20	30	5am-1am

4.4 Financial Characteristics

Cost Efficiency

Regarding the operating cost per rider, it becomes very clear that the three agencies in the Atlanta region have the highest operating cost per rider and therefore are the least cost efficient (Table 9). The agency with the lowest ridership (GCT) has the highest cost per rider. The MVG in Munich shows a very good result with an expense of only $0.83 per rider. The HHA in Hamburg and the VBK in Karlsruhe have very similar costs per rider while the BVG in Berlin does a little better and the Üstra in Hanover does a little worse. This is most likely due to regional differences and the fact that the population density in Berlin is higher than in the other cities.

When it comes to the operating costs per passenger mile the picture gets somewhat turned around. Now the agencies in the Atlanta region are more efficient than the three agencies in Germany for which data was available. The Üstra in Hanover has the highest expenses per passenger mile while MARTA has a higher cost efficiency than the BVG in Berlin. The bus-only agencies CCT and GCT have the highest cost efficiency on a passenger mile basis, which is probably due to the fact that they do not have to provide expensive rail infrastructure like all other agencies, but still transport their riders over long distances. (Table 9)

Just like in the "Operational Characteristics" section these results again suggest that riders in the Atlanta region travel longer distances than their counterparts in Germany thus causing high costs per rider, but lower costs per passenger mile.

Fare System

The trend that Atlanta riders seem to travel longer distances than the riders in the German cities is reinforced by the fare system in the region. The Atlanta agencies are the only agencies in the comparison that have a flat fare system for their entire service area. (Table 9) All German agencies have a zonal system in which the whole region is divided into zones. For all trips taking place within one zone a flat fare is applied. If zone borders have to be crossed on any trip the fare rises accordingly. The S-Bahn Hanover additionally has a distance-based fare system for trips taking place to and from places outside of the zonal system.

The three Atlanta agencies also have relatively low fares when compared to the German agencies. Especially for long trips, passengers in all German cities have to pay more than the $2 fare that applies for all local buses in Atlanta and the MARTA rail system. Only the express fare charged by CCT and GCT exceeds some of the top ticket prices of the urban agencies in Germany (BVG, HHA, MVG).

Cost Recovery Factor

The agency characteristics described in the cost efficiency and fare system categories are reflected in the cost recovery factor of the respective agencies. Because of the flat fare system that does not account for the high cost per passenger caused by the long travel distances, the three agencies in Atlanta have the lowest cost recovery factor. (Table 9) Only 28% of the operating cost of the MARTA system is covered by fare revenue. The VBK in Karlsruhe on the other hand covers 70% of its operating expenses by fare revenue and even the heavily rail dependent (and therefore expensive) BVG in Berlin has been able to cover at least 55% of its expenses with its fare revenue.

All in all it seems that compared to the agencies in the Atlanta region the German agencies have done a better job of adjusting their fare structure and ticket prices to the customers' travel behavior while keeping costs per rider and passenger mile on a relatively low level. However, despite high population density and high ridership, none of the systems managed to break even and all have to be financially supported by the government, which is generally typical for public transit systems.

Table 9 - Financial Characteristics of the Transit Agencies

City	System	operating cost		cost recovery factor	fare structure	ticket prices [$]
		per rider	per passenger mile			
Atlanta	MARTA Rail	$2.39	$0.46	0.28	flat	2
	MARTA Bus				flat	2
	CCT BUS	$3.84	$0.43	0.28	flat	2 (expr. 4)
	GCT BUS	$5.43	$0.32	0.37	flat	2 (expr. 3)
Berlin	S-Bahn	N/A	N/A	N/A	zones	1.96-4.2
	U-Bahn	$1.23	$0.48	0.55	zones	1.92-3.22
	Streetcar				zones	1.92-3.22
	Bus				zones	1.92-3.22
Hamburg	S-Bahn	N/A	N/A	N/A	zones	3.92-10.71
	U-Bahn	$1.67	$0.60	0.67	zones	1.82-3.92
	Bus				zones	1.82-3.92
Munich	S-Bahn	N/A	N/A	N/A	zones	3.5-14
	U-Bahn	$0.83	N/A	N/A	zones	1.68-7.0
	Streetcar				flat within zone	1.68-3.5
	Bus				flat within zone	1.68-3.5
Hanover	S-Bahn	N/A	N/A	N/A	zones/distance	3.22-24.36
	LRT	$2.02	$0.69	0.57	zones	1.96-4.2
	Bus				zones	1.96-4.2
Karlsruhe	Streetcar	$1.65	N/A	0.70	flat within zone	2.38-3.08
	Bus				flat within zone	2.38-3.08
	S-Bahn	N/A	N/A	N/A	zones	2.38-7.7

CHAPTER 5

CONCLUSION

5.1 Differences and Similarities Between the Transit Systems

After comparing all the respective network, operational and financial parameters, it can be concluded that the transit service in the Atlanta region lags behind the service offered in the five German cities to which it was compared. The German systems all offer much more rail service with all of them having at least two different rail systems: a short distance urban rail system such as a U-Bahn, a light rail or a streetcar system and a regional system such as an S-Bahn or Regional-Stadtbahn system.

This extent of rail transit in Germany can most likely be explained by two facts. First, the population density and distribution in the German cities is much higher than that of the city of Atlanta. Many people still live close to the city center or at least in the city itself while in Atlanta the city only represents a small share of the region's population. This residential structure in German cities makes it much more convenient for transit operators to offer rail-guided (and even bus-based) transit services because the number of people living within walking distance of each station is higher. Secondly, the right of transit that is embedded into the German law based on the social principle in the German constitution has by itself stimulated the development of strong rail transit systems and has prevented them from being shut down during the rise of the automobile.

The high population density and limited parking availability in the cities combined with the public affinity for fast and reliable rail transit have created urban transportation systems that heavily rely on public transportation and attract a substantial number of choice riders helping the transit agencies to improve financial efficiency.

The Atlanta region on the other hand has tried to counteract the dominance of the automobile and to meet the demand for relatively few but long transit trips by implementing an extensive bus network much larger than the bus networks in the five German cities. However, the residential structure in the Atlanta region again seems to make it very hard to attract a substantial number of riders so that the German bus systems of comparable size all attract more riders than the Atlanta bus system. Another cause for the relatively low bus ridership can also be the relatively long headways and limited service times on many of the Atlanta bus routes. It seems as if the transit agencies are only maintaining a very basic service on most lines due to absence of funds and low choice ridership of people who do not depend on transit and can choose between different modes of transportation. However, this basic service fails to attract choice riders and thus it also fails to create a high overall ridership such as in the German transit systems.

The lack of rail service, which only covers a small part of the Atlanta region, does not make the public transit system particularly attractive to choice riders, unless they live close to one of the few rail stations. The financial effectiveness of the Atlanta transit system is furthermore undermined by the counterproductive fare system. Riders taking long transit trips do not warrant a flat fare system that treats everybody the same, but rather suggests a distance-based/zonal fare system. In this way, the “expensive” riders who are traveling longer distances would produce equivalent revenue and have a larger share in the financing of the transit system.

Another important finding of this research was that the MARTA rail system has distinct differences to the characteristics of the German U-Bahn systems regarding station spacing, operational characteristics and ridership. The MARTA rail system seems much more to be a mixture of a German U-Bahn system and S-Bahn system having the station spacings of a typical S-Bahn system while operating on an entirely exclusive right of way with no level-grade crossings. This special configuration of its network has presumably been the best way to adapt to the special challenges that rail service in the Atlanta region has to face: low density, high sprawl and a very large region that has to be covered which should always be kept in mind when comparing the MARTA system to other systems in the United States and around the world.

5.2 Possible Applications in Atlanta

Given the results of this study, it can be inferred that some of the elements of German transit systems could have an application in the Atlanta region helping to improve the current situation while others are not likely to be applicable. Low population density and long trip distances do not warrant the implementation of short distance high load transit like subways and streetcars. The resemblance between the German S-Bahn systems and the MARTA rail systems, however, suggest that some of the S-Bahn system characteristics could be applicable in Atlanta as well. Given the small coverage of the rail transit system in the Atlanta region, especially the non-existence of rail transit in southern Cobb and Gwinnett Counties, it could be warranted to extend rail lines from the MARTA rail system to these suburban centers. These lines should have the characteristics of S-Bahn transit with a limited number of level grade crossings (if necessary) and large station spacing in sparsely populated areas.

The hurdle for letting these trains run into downtown and midtown Atlanta on the MARTA rail lines would be to make them compatible with the third rail that is used on MARTA tracks. Experiences from Hamburg and Karlsruhe show that this is possible and has successfully been implemented elsewhere. Trains could run electrified using MARTA's third rail in the city center and switch to diesel power or an overhead catenary electric line in the suburbs. This way even existing track could be used for the extension of the rail transit system.

Another possibility to move rail transit in the Atlanta region closer to the potential riders is to implement a combined light-rail/heavy-rail two system streetcar like the Regio-Stadtbahn system in Karlsruhe. This way trains could switch from fast overland sections on existing track to slower inner city sections on newly built light-rail track connecting right into the activity centers of the region.

5.3 Evaluation of Study and Further Research

Given the results of this study, it can be claimed that most of the chosen parameters and measures provided a very conclusive picture of the differences in the respective transit systems. Although further parameters such as train and bus average speeds and train and bus capacity could be included in future comparisons to provide an even broader overview the limited number of parameters used in this study already supports a lot of very interesting findings that are shown in the previous sections.

For further research it would definitely also be an interesting approach to include different and more transit systems in other US cities to see if the characteristics of the Atlanta region are similar to those in other parts of the US and to see how the transit systems of other US cities (such as San Francisco, Washington D.C., Portland or New York) that have stronger rail transit networks compare to the German transit systems.

REFERENCES

1. Bundesjustizministerium. *Eisenbahn-Bau- und Betriebsordnung*. 1967 [cited 2011 5/31]; Available from: http://www.gesetze.juris.de/bundesrecht/ebo/gesamt.pdf.

2. Bundesjustizministerium. *Straßenbahn-Bau- und Betriebsordnung*. 1987 [cited 2011 5/31]; Available from: http://bundesrecht.juris.de/bundesrecht/strabbo_1987/gesamt.pdf.

3. Cervero, R., *The Transit Metropolis - A Global Inquiry.* 1998.

4. Lewyn, M., *Sprawl in Europe and America.* San Diego Law Review, 2009. **46**(1): p. 85-112.

5. Knoflacher, H., *Success and failures in urban transport planning in Europe--understanding the transport system.* Sadhana, 2007. **32**(4): p. 293-307.

6. Sampaio, B.R., *Efficiency analysis of public transport systems.* Lessons for institutional planning, 2008. **42**(3): p. 445-454.

7. Reddy, A., *Subway productivity, profitability, and performance.* Transportation Research Record, 2010. **ISSU**(2143): p. 48-58.

8. Daganzo, C.F., *Structure of competitive transit networks.* Transportation Research Part B-methodological, 2010. **44**(4): p. 434-446.

9. Wunsch, P., *Cost and Productivity of Major Urban Transit Systems in Europe.* An Exploratory Analysis, 1996. **30**(2): p. 171-186.

10. FTA. *National Transit Database*. 2011 [cited 2011 02/10/2011]; Available from: http://www.ntdprogram.gov/ntdprogram/.

11. Deutscher_Bundestag, *Basic Law for the Federal Republic of Germany*. 2010, Deutscher Bundestag Public Relations Divison: Berlin.

12. Deutscher_Bundestag. *Raumordnungsgesetz*. 2008 [cited 2011 5/22]; Available from: http://www.gesetze-im-internet.de/bundesrecht/rog_2008/gesamt.pdf.

13. Deutscher_Bundestag. *Gesetz zur Regionalisierung des öffentlichen Personennahverkehrs - Regionalisierungsgesetz*. 1993 [cited 2011 5/22]; Available from: http://bundesrecht.juris.de/bundesrecht/regg/gesamt.pdf.

14. Deutscher_Bundestag. *Gemeindeverkehrsfinanzierungsgesetz*. 1971 [cited 2011 5/22]; Available from: http://bundesrecht.juris.de/bundesrecht/gvfg/gesamt.pdf.

15. The_Continental_Congress. *The Constitution of the United States of America*. 1783 [cited 2011 5/30]; Available from: http://www.usconstitution.net/const.html.

16. Metropolitan_Atlanta_Rapid_Transit_Authority. *History of MARTA*. 2006 [cited 2011 5/29]; Available from: http://www.itsmarta.com/marta-past-and-future.aspx.

17. FTA. *Grants and Financing*. 2010 [cited 2011 5/30]; Available from: http://www.fta.dot.gov/grants_financing.html.

18. Berlin-Brandenburg, A.f.S. *Statistik Berlin Brandenburg*. 2011 03/12/2011; Available from: http://www.statistik-berlin-brandenburg.de/.

19. Verkehrsverbund-Berlin-Brandenburg. *Über den VBB/Das Unternehmen*. 2011 [cited 2011 03/12]; Available from: http://www.vbbonline.de/index.php?cat=4&sCat=31&id_language=1.

20. Berliner-Verkehrsbetriebe. *BVG Verkehrsmittel und Linien*. 2011; Available from: http://www.bvg.de/index.php/de/3712/name/Verkehrsmittel+%26+Linien.html.

21. S-Bahn-Berlin. *S-Bahn Berlin History*. 2011 [cited 2011 03/09]; Available from: http://www.s-bahn-berlin.de/unternehmen/firmenprofil/historie_teil1.htm.

22. S-Bahn-Berlin. *S-Bahn Berlin Liniennetz*. 2011 [cited 2011 03/09]; Available from: http://www.s-bahn-berlin.de/stadtplan/view/Liniennetz.

23. Berliner-Verkehrsbetriebe. *BVG Liniennetz*. 2011 [cited 2011 03/13]; Available from: http://www.bvg.de/index.php/de/3713/name/Liniennetz.html.

24. Berliner-Verkehrsbetriebe. *Die U-Bahn, Geschichte der U-Bahn*. 2011 [cited 2011 03/13]; Available from: http://www.bvg.de/index.php/de/3917/name/Geschichte+der+U-Bahn.html.

25. Berliner-Verkehrsbetriebe. *Lückenschluss U5*. 2011 [cited 2011 03/13]; Available from: http://www.bvg.de/index.php/de/3904/name/Lueckenschluss+U5.html.

26. Berliner-Verkehrsbetriebe. *Fahrzeuge der Berliner U-Bahn*. 2011 [cited 2011 03/13]; Available from: http://www.bvg.de/index.php/de/281001/name/Fahrzeuge+der+Berliner+U-Bahn.html.

27. Berliner-Verkehrsbetriebe. *Die Geschichte der Berliner Straßenbahn*. 2011 [cited 2011 03/13]; Available from: http://www.bvg.de/index.php/de/3926/name/Geschichte.html.

28. Berliner-Verkehrsbetriebe. *Die Straßenbahn - Straßenbahnnetz*. 2011 [cited 2011 03/13]; Available from: http://www.bvg.de/index.php/de/88115/name/Strassenbahnnetz.html.

29. Berliner-Verkehrsbetriebe. *Die Geschichte des Berliner Omnibusverkehrs*. 2011 [cited 2011 03/13]; Available from: http://www.bvg.de/index.php/de/3931/name/Geschichte.html.

30. Statistisches_Bundesamt. *Statistisches Jahrbuch 2010 für die Bundesrepublik Deutschland*. 2011 [cited 2011 03/28]; Available from: http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/SharedContent/Oeffentlich/B3/Publikation/Jahrbuch/Bevoelkerung,property=file.pdf.

31. Hamburger-Verkehrs-Verbund. *Unternehmensbroschuere*. 2005 [cited 2011 4/8]; Available from: http://www.hvv.de/pdf/wissenwertes/unternehmensbroschuere.pdf.

32. Eisenbahn_Altona-Kaltenkirchen-Neumünster. *Über uns AKN*. 2011 [cited 2011 4/12]; Available from: http://www.akn.de/ueber-uns/die-akn/.

33. S-Bahn-Hamburg. *Unternehmensgeschichte*. 2011 [cited 2011 4/8]; Available from: http://www.s-bahn-hamburg.de/s_hamburg/view/wir/unternehmensgeschichte.shtml.

34. Hamburger-Verkehrs-Verbund. *Fahrzeuge*. 2011 [cited 2011 4/8]; Available from: http://www.s-bahn-hamburg.de/s_hamburg/view/wir/fahrzeuge.shtml.

35. Hamburger-Verkehrs-Verbund. *Daten, Zahlen, Fakten*. 2011 [cited 2011 4/8]; Available from: http://www.s-bahn-hamburg.de/s_hamburg/view/wir/daten-zahlen-fakten.shtml.

36. Hamburger-Verkehrs-Verbund. *Streckennetz*. 2008 [cited 2011 4/8]; Available from: http://www.s-bahn-hamburg.de/s_hamburg/view/mdb/s_hamburg/wir/pdf/MDB53919-netzplan_neu.pdf.

37. Hamburger-Hochbahn_AG. *Hundert Jahre Hochbahn*. 2006 [cited 2011 4/11]; Available from: http://www.100-jahre-hochbahn.de/.

38. Hamburger-Hochbahn_AG. *U-Bahn Netz*. 2011 [cited 2011 4/11]; Available from: http://www.hochbahn.de.

39. Tageszeitung, D. *Erste Regierungserklärung von Olaf Scholz*. 2011 [cited 2011 4/11]; Available from: http://www.taz.de/1/nord/hamburg/artikel/1/keine-visionen/.

40. Hamburger-Hochbahn_AG. *Bus Netz*. 2011 [cited 2011 4/11]; Available from: http://www.hochbahn.de.

41. Münchener_Verkehrs-_und_Tarifverbund. *MVV Verbundbericht 2009*. 2009 [cited 2011 4/19]; Available from: http://www.mvv-muenchen.de/web4archiv/objects/download/mvv-verbundbericht_2009.pdf.

42. Münchener_Verkehrs-_und_Tarifverbund. *MVV Verbundgeschichte*. 2011 [cited 2011 4/19]; Available from: http://www.mvv-muenchen.de/de/home/dermvv/verbundgeschichte/index.html.

43. DB-Regio. *S-Bahn München - Historie*. 2011 [cited 2011 5/3]; Available from: http://www.s-bahn-muenchen.de/s_muenchen/view/wir/historie.shtml.

44. Münchener_Verkehrs-_und_Tarifverbund. *Liniennetzplan*. 2010 [cited 2011 5/3]; Available from: http://www.mvv-muenchen.de/web4archiv/objects/download/schnellbahn-netzplan2011.pdf.

45. DB-Regio. *S-Bahn München - Fahrplaninformationen*. 2011 [cited 2011 5/3]; Available from: http://www.s-bahn-muenchen.de/s_muenchen/view/fahrplan/fahrplaene-ueb.shtml.

46. Münchener_Verkehrsgesellschaft. *MVG - Zeitreise*. 2010 [cited 2011 5/26]; Available from: http://www.mvg-mobil.de/ueberuns/zeitreise.html.

47. Münchener_Verkehrsgesellschaft. *MVG - Tramnetz*. 2010 [cited 2011 5/26]; Available from: http://www.mvg-mobil.de/netzplaene/images/tramnetz.pdf.

48. Münchener_Verkehrsgesellschaft. *MVG - Verkehrslinienplan Stadt*. 2010 [cited 2011 5/26]; Available from: http://www.mvg-mobil.de/netzplaene/images/vl-stadt.pdf.

49. Münchener_Verkehrsgesellschaft. *Liniennetzpläne*. 2010 [cited 2011 5/29]; Available from: http://www.mvg-mobil.de/netzplaene/index.html.

50. Stadt_Hannover. *Hannover in Zahlen*. 2011 [cited 2011 4/12]; Available from: http://www.hannover.de/de/buerger/wahlen/zahlen_daten/zahlenlh/index.html.

51. Region_Hannover. *Region Hannover*. 2011 [cited 2011 4/12]; Available from: http://www.hannover.de/de/buerger/verwaltungen/rh_dez_fb/.

52. Großraum-Verkehr_Hannover. *Der GVH stellt sich vor*. 2011 [cited 2011 4/12]; Available from: http://www.gvh.de/gvh.html.

53. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Üstra: Über uns*. 2011 [cited 2011 4/12]; Available from: http://www.uestra.de/unternehmen.html.

54. RegioBus_Hannover. *RegioBus Hannover - Portrait*. 2011 [cited 2011 4/12]; Available from: http://www.regiobus.de/unternehmen/portrait.htm.

55. S-Bahn_Hannover. *Unternehmensgeschichte*. 2011 [cited 2011 4/12]; Available from: http://www.bahn.de/s_hannover/view/wir/unternehmensgeschichte.shtml.

56. Großraum-Verkehr_Hannover. *Schienennetz*. 2011 [cited 2011 4/12]; Available from: http://www.gvh.de/netzplaene.html.

57. Region_Hannover. *Der Nahverkehrsplan 2008*. 2008 [cited 2011 4/12]; Available from: http://www.hannover.de/de/wirtschaft/mobilitaet/RH_Nahverkehr/RH_Wer_macht_was/nvp2008_text.html.

58. S-Bahn_Hannover. *Data provided by agency*. 2011 [cited 2011 5/27].

59. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Üstra-Chronik*. 2011 [cited 2011 4/17]; Available from: http://www.uestra.de/chronik.html?&L=2.

60. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Üstra Stadtbahnnetz*. 2010 [cited 2011 4/17]; Available from: http://www.uestra.de/fileadmin/gvh/downloads/Plaene/2011/GVH_Stadtbahnnetz_WEB.pdf.

61. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Einsteigen: Die Stadtbahn*. 2008 [cited 2011 4/17]; Available from: http://www.uestra.de/fileadmin/uestra/downloads/themenbroschueren/Stadtbahnbroschuere.pdf.

62. Üstra_Hannoversche_Verkehrsbetriebe_AG. *GVH Busnetz*. 2010 [cited 2011 4/17]; Available from: http://www.uestra.de/fileadmin/gvh/downloads/Plaene/2011/GVH_Busnetz_WEB.pdf.

63. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Einsteigen: Der Stadtbus*. 2008 [cited 2011 4/17]; Available from: http://www.uestra.de/fileadmin/uestra/bilder/themenbroschueren/Stadtbus.pdf.

64. Stadt_Karlsruhe. *Statistisches Informationssystem Karlsruhe*. 2010 [cited 2011 5/27]; Available from: http://www1.karlsruhe.de/Stadtentwicklung/siska/sache02.php.

65. Karlsruher_Verkehrsverbund_GmbH. *Das Karlsruher Modell*. 2010 [cited 2011 5/27]; Available from: http://www.kvv.de/unternehmen-kvv/karlsruher-modell.html.

66. Karlsruher_Verkehrsverbund_GmbH. *Verbundbericht 2009*. 2009 [cited 2011 5/27]; Available from: http://www.kvv.de/fileadmin/user_upload/kvv/dokumente/der_kvv/KVV%20Verbundbericht%202009.pdf.

67. Albtal_Verkehrsgesellschaft_mbH. *Geschichte der AVG*. 2009 [cited 2011 5/28]; Available from: http://www.avg.info/geschichte.html.

68. Karlsruher_Verkehrsverbund_GmbH. *Linienplan Schienennetz*. 2010 [cited 2011 5/28]; Available from: http://www.kvv.de/fileadmin/user_upload/kvv/dokumente/netz/liniennetz/2011/L0SCHI_DEZ10_NEU%2017.12.2010.pdf.

69. Albtal_Verkehrsgesellschaft_mbH. *Linienübersicht*. 2010 [cited 2011 5/28]; Available from: http://www.avg.info/oepnv.html.

70. Dufresne, M. *Geschichte der Straßenbahn Karlsruhe*. 2007 [cited 2011 5/28]; Available from: http://home.arcor.de/astrafa/tramway/karlsruhe/geschichte.htm.

71. Karlsruher_Verkehrsverbund_GmbH. *Busliniennetz Karlsruhe Stadt*. 2010 [cited 2011 5/28]; Available from: http://www.kvv.de/fileadmin/user_upload/kvv/dokumente/netz/liniennetz/2011/L01BUS.pdf.

72. U.S._Census_Bureau. *U.S. Census 2010*. 2010 [cited 2011 04/11]; Available from: http://2010.census.gov/2010census/data/apportionment-dens-text.php.

73. Tankersley, M. *Atlanta's Streetcars of the Nineteenth Century*. [cited 2011 5/29]; Available from: http://www.newsouthassoc.com/tank/index.html.

74. Metropolitan_Atlanta_Rapid_Transit_Authority. *Interactive System Map*. 2010 [cited 2011 5/29]; Available from: http://www.itsmarta.com/system-map.aspx.

75. Cobb_Community_Transit. *CCT System Map*. 2011 [cited 2011 5/29]; Available from: http://dot.cobbcountyga.gov/cct/downloads/January2011CCTMap.pdf.

76. Gwinnett_County_Transit. *GCT Local Routes*. 2010 [cited 2011 5/29]; Available from:

http://www.gwinnettcounty.com/static/departments/transportation/pdf/GCTAdoptedRoutes.pdf.

77. Metropolitan_Atlanta_Rapid_Transit_Authority, *Agency Information*. 2011: Atlanta.

78. Cobb_Community_Transit. *CCT Routes*. 2011 [cited 2011 5/20]; Available from: http://dot.cobbcountyga.gov/cct/route-schedules.htm.

79. Cobb_Community_Transit, *Agency Information*. 2011: Atlanta.

80. Gwinnett_County_Transit, *Agency Information*. 2011: Atlanta.

81. Verkehrsverbund-Berlin-Brandenburg, *Agency Information*. 2010: Berlin.

82. S-Bahn_Berlin. *Zahlenspiegel*. 2009 [cited 2011 4/12]; Available from: http://www.s-bahn-berlin.de/unternehmen/firmenprofil/kurzfassung.htm.

83. Berliner-Verkehrsbetriebe. *BVG in Zahlen*. 2011 [cited 2011 4/13]; Available from: http://www.bvg.de/index.php/de/3900/name/BVG+in+Zahlen.html.

84. S-Bahn_Hamburg_GmbH. *Daten, Zahlen, Fakten*. 2011 [cited 2011 5/17]; Available from: http://www.s-bahn-hamburg.de/s_hamburg/view/wir/daten-zahlen-fakten.shtml.

85. Hamburger-Hochbahn_AG. *Hamburger Hochbahn AG, Unternehmensbericht 2009*. 2009 [cited 2011 3/22]; Available from: http://www.hochbahn.de/wps/wcm/connect/39135980433ae86d83c6dbed8c1618a7/HOCHBAHN_UB_2009_DE.pdf?MOD=AJPERES.

86. Hamburger-Hochbahn_AG, *Agency Information*. 2011: Hamburg.

87. DB-Regio. *S-Bahn München, Daten und Fakten*. 2011 [cited 2011 3/23]; Available from: http://www.s-bahn-muenchen.de/s_muenchen/view/wir/daten_fakten.shtml.

88. Münchener_Verkehrsgesellschaft. *MVG in Zahlen 2009*. 2009 [cited 2011 3/23]; Available from: http://www.mvg-mobil.de/ueberuns/images/mvg_in_zahlen_s.pdf.

89. DB-Regio. *Zahlen, Daten, Fakten zur S-Bahn Hannover*. 2009 [cited 2011 3/24]; Available from: http:/www.bahn.de/s_hannover/view/wir/unternehmen.shtml.

90. S-Bahn_Hannover, *Agency Information*. 2011: Hannover.

91. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Üstra Stadtbahn Broschüre 2009*. 2009 [cited 2011 3/24]; Available from: http://www.uestra.de/fileadmin/uestra/downloads/themenbroschueren/Stadtbahn_Broschuere_web_Nachdruck_2009.pdf.

92. Üstra_Hannoversche_Verkehrsbetriebe_AG, *Agency Information.* 2011.

93. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Stadtbus Info*. 2011 [cited 2011 3/23]; Available from: http://www.uestra.de/stadtbus.html.

94. Albtal_Verkehrsgesellschaft_mbH. *AVG Geschäftsbericht 2009*. 2009 [cited 2011 4/23]; Available from: http://www.avg.info/fileadmin/user_upload/avg/pdf/GB/AVG_GB_2009.pdf.

95. Verkehrsbetriebe_Karlsruhe. *Verkehrsbetriebe Karlsruhe GmbH, Geschäftsbericht 2009*. 2009 [cited 2011 5/20]; Available from: http://www.vbk.info/fileadmin/user_upload/vbk/Dokumente/Geschaeftsberichte/VBK_GB_2009%5B1%5D.pdf.

96. Verkehrsbetriebe_Karlsruhe, *Agency Information.* 2011.

97. Metropolitan_Atlanta_Rapid_Transit_Authority. *MARTA Station Schedules*. 2011 [cited 2011 5/23]; Available from: http://www.itsmarta.com/ew-fiv.aspx.

98. Cobb_Community_Transit. *CCT, Routes and Schedules*. 2011 [cited 2011 5/23]; Available from: http://dot.cobbcountyga.gov/cct/route-schedules.htm#10.

99. Gwinnett_County_Transit. *GCT Routes & Schedules*. 2011 [cited 2011 5/23]; Available from: http://www.gwinnettcounty.com/portal/gwinnett/Departments/Transportation/GwinnettCountyTransit/RoutesandSchedules.

100. Verkehrsverbund-Berlin-Brandenburg. *VBB Fahrinfo*. 2011 [cited 2011 5/25]; Available from: http://www.vbb-fahrinfo.de/hafas/p2w/query-p2w.exe/dn?whichTask=hst&p2wType=st&.

101. Berliner-Verkehrsbetriebe. *BVG Geschäftsbericht 2009*. 2009 [cited 2011 4/13]; Available from: http://www.bvg.de/index.php/de/3902/name/Geschaeftsbericht+.html.

102. S-Bahn_Hamburg_GmbH, *Agency Information*. 2011: Hamburg.

103. Hamburger-Verkehrs-Verbund. *HVV Fahrpläne*. 2011 [cited 2011 5/27]; Available from: http://www.hvv.de/fahrplaene/fahrplaene-als-pdf/.

104. S-Bahn_München, *Agency Information*. 2011.

105. Münchener_Verkehrs-_und_Tarifverbund. *MVG Fahrpläne*. 2011 [cited 2011 5/25]; Available from: http://www.mvg-mobil.de/fahrplaene/minifahrplaene.html.

106. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Üstra Themenbroschüre Stadtbus*. 2010 [cited 2011 3/23]; Available from: http://www.uestra.de/fileadmin/uestra/bilder/themenbroschueren/Stadtbus.pdf.

107. Karlsruher_Verkehrsverbund_GmbH. *KVV Kursbuch*. 2011 [cited 2011 5/24]; Available from: http://www.kvv.de/fileadmin/user_upload/kvv/dokumente/fahrplan/2011/Kursbuch_2011.pdf.

108. Metropolitan_Atlanta_Rapid_Transit_Authority. *MARTA Fares*. 2011 [cited 2011 5/23]; Available from: http://www.itsmarta.com/fares-passes.aspx.

109. Cobb_Community_Transit. *CCT Fares*. 2011 [cited 2011 5/23]; Available from: http://dot.cobbcountyga.gov/cct/cct-fares.htm.

110. Gwinnett_County_Transit. *GCT Fare Information*. 2011 [cited 2011 5/23]; Available from: http://www.gwinnettcounty.com/portal/gwinnett/Departments/Transportation/GwinnettCountyTransit/PassesandTickets.

111. Berliner-Verkehrsbetriebe. *BVG Tarifübersicht*. 2011 [cited 2011 5/20]; Available from: http://www.bvg.de/index.php/de/3786/name/Tarifuebersicht.html.

112. Hamburger-Verkehrs-Verbund. *Tarifinformation*. 2011 [cited 2011 5/25]; Available from: http://www.hvv.de/pdf/wissenwertes/downloads/Fahrkarten_Preise_1-2011.pdf.

113. S-Bahn_München. *Tarifinformationen*. 2011 [cited 2011 5/23]; Available from: http://www.s-bahn-muenchen.de/s_muenchen/view/angebot/tickets/einzelfahrkarte.shtml.

114. Stadtwerke-München. *Stadtwerke München, Geschäftsbericht 2009*. 2009 [cited 2011 3/03]; Available from: http://www.swm.de/dms/swm/dokumente/unternehmen/swm/geschaeftsbericht-2009.pdf.

115. Münchener_Verkehrsgesellschaft. *MVG Tarife*. 2011 [cited 2011 5/20]; Available from: http://www.mvg-mobil.de/tarife/gelegenheitsfahrer.html.

116. S-Bahn_Hannover. *Tarifinformationen*. 2011 [cited 2011 5/20]; Available from: http://www.s-bahn-hannover.de/s_hannover/view/index.shtml.

117. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Geschäftsbericht Üstra 2009*. 2009 [cited 2011 4/03]; Available from: http://www.uestra.de/fileadmin/uestra/downloads/geschaeftsberichte/2010/GB_2009_Einzelabschluss_web.pdf.

118. Üstra_Hannoversche_Verkehrsbetriebe_AG. *Üstra Tickets*. 2011 [cited 2011 5/20]; Available from: http://www.uestra.de/tickets0.html.

119. Karlsruher_Verkehrsverbund_GmbH. *KVV Fahrkartenauskunft*. 2011 [cited 2011 5/21]; Available from: http://www.kvv.de/fahrkarten/fahrkarten-preise/einzelfahrkarten.html.

120. U.S._Census_Bureau. *US Census - Quickfacts*. 2011 [cited 2011 5/27]; Available from: http://quickfacts.census.gov/qfd/states/13/13121.html.

121. Hamburger-Verkehrs-Verbund. *HVV in Zahlen*. 2011 [cited 2011 5/23]; Available from: http://www.hvv.de/ueber-uns/hvv-in-zahlen/.

122. Großraum-Verkehr_Hannover. *GVH Bilanz 2009/2010*. 2009 [cited 2011 3/28]; Available from: http://www.gvh.de/gvh.html.

123. Karlsruher_Verkehrsverbund_GmbH. *Zahlen, Daten und Leistungen*. 2009 [cited 2011 5/20]; Available from: http://www.kvv.de/unternehmen-kvv/daten.html.